ISIS

INDIVIDUALIZED SCIENCE INSTRUCTIONAL SYSTEM

HOUSE POWER

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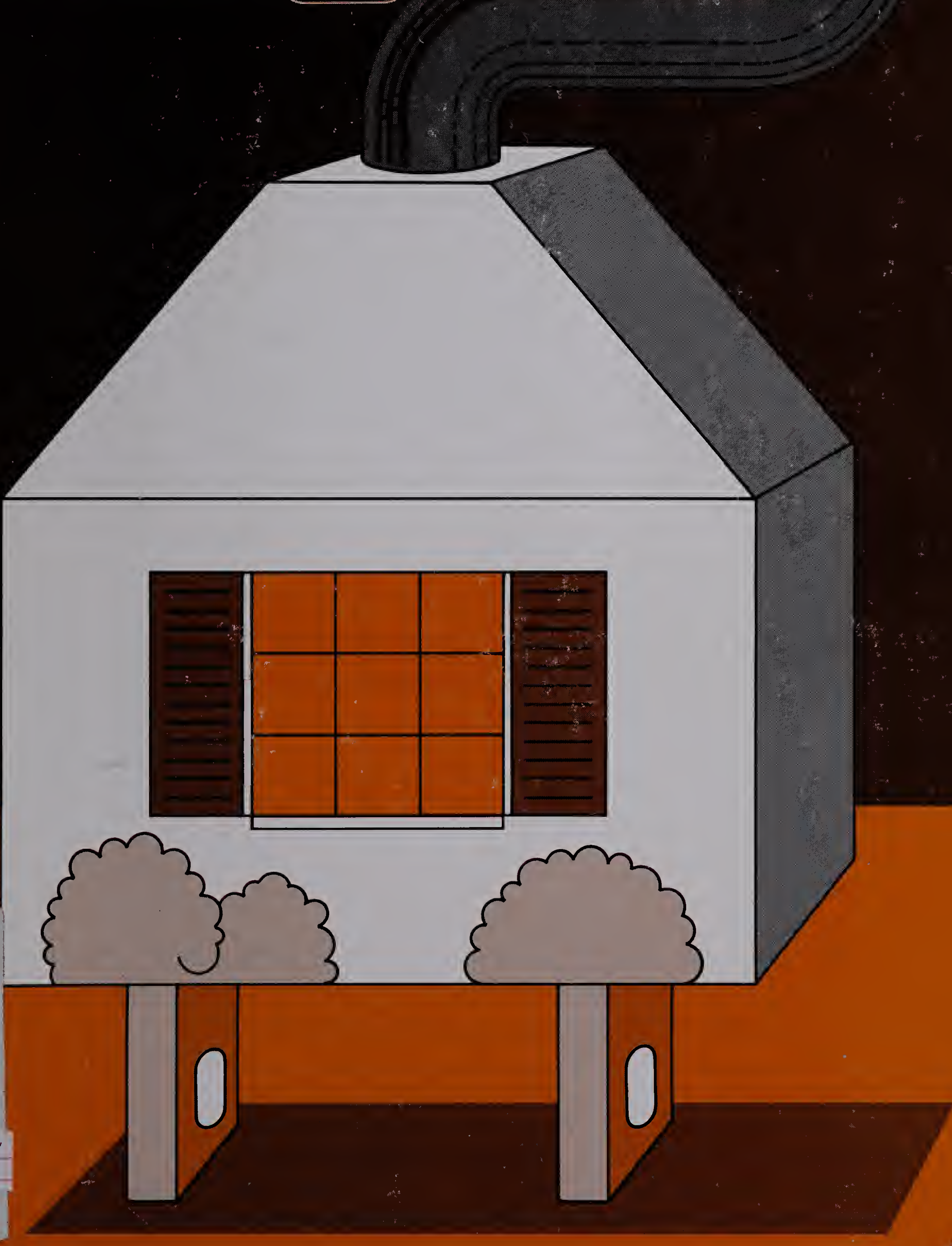

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HOUSE POWER

ANNOTATED TEACHER'S EDITION

Ginn and Company

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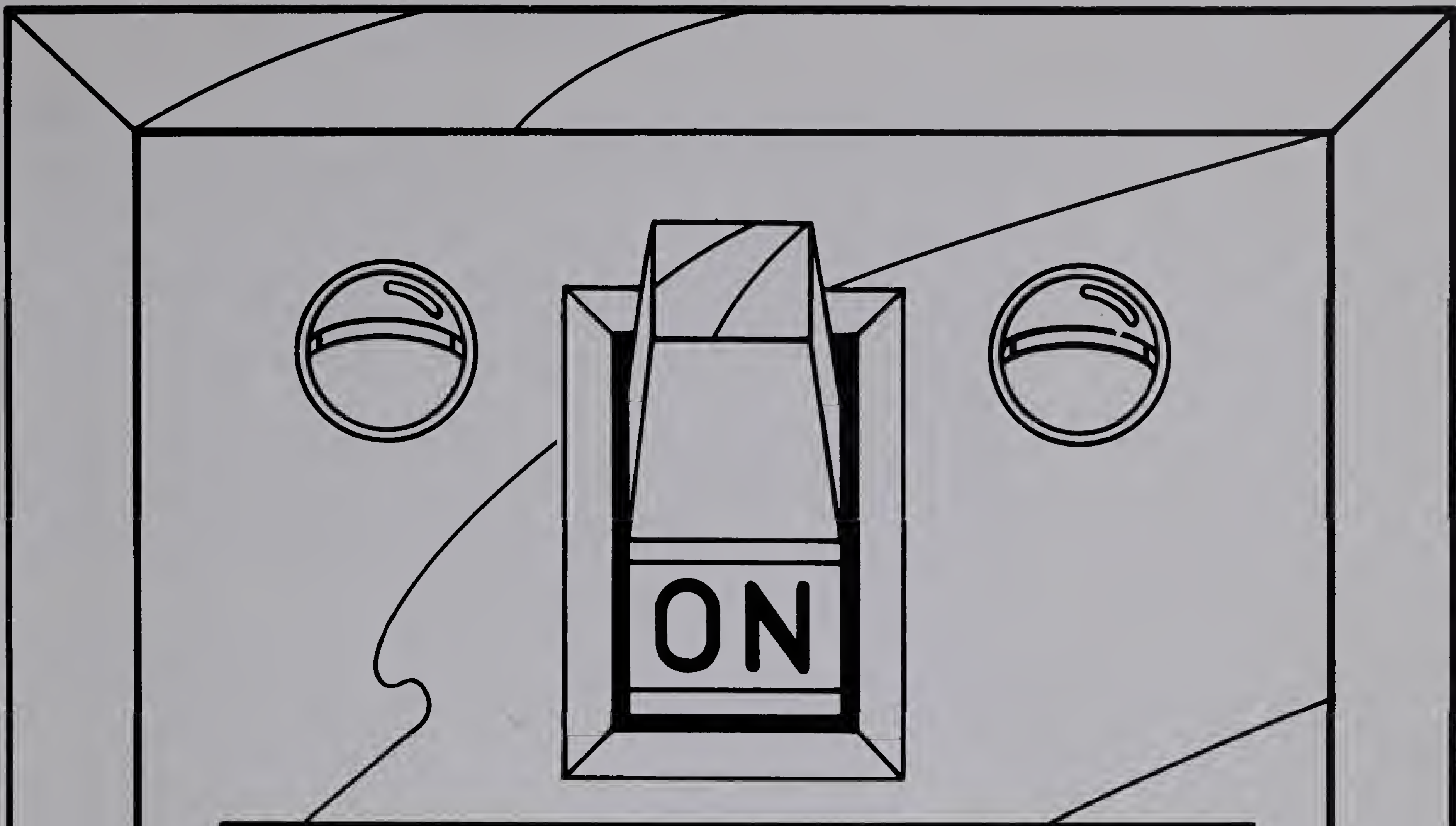


Contents

Overview

House Power investigates electrical phenomena commonly found around the home. Starting with basic safety and test procedures, the activities introduce the terms and simple processes that relate to small electrical appliances and home wiring. Students construct simple circuits, use test equipment, analyze the wiring in their homes, and do basic calculations and electrical repairs. The activities set a pattern for the understanding and safe use of electrical equipment.

House Power provides particular relevance when one considers current trends toward greater use of electrical energy at home and the increasing cost of this energy. Students are given first-hand knowledge of the limitations necessary to consider when expanding the use of electrical energy in the home.

Although *House Power* was designed to be part of a general science or physics curriculum, the practical content of core and excursion activities should appeal to most science students.

Organization

This minicourse contains seven core activities, five advanced activities, and four excursion activities. The planning activities must be done first in each section. Activity 2, if it must be done, should be completed before other core activities. Activity 5 should be done before Activity 6. The other core activities may be done in any order.

Core activities present the basics needed for understanding electrical usage at home. Parallels are made between a system of water pipes and an electrical system, with the ideas of current and voltage emphasized. Students use a circuit tester to establish the concepts of "hot" wires and grounding. The effect of electrical load on wire size is investigated to illustrate how one can judge when a branch circuit may be overloaded. First aid procedures in the case of electric shock are explained.

In the advanced activities students define, measure, and calculate electric current, potential differences, electric charge, resistance, and electrical energy. The differences between AC and DC are also explored and represented in graphic form. If Activity 9 needs to be done, it should be done before Activity 10.

In excursion activities, students will replace a defective plug, build and operate a simple thermostat, draw a home wiring diagram and label the circuits at home.

Materials and Equipment

The following table shows the quantity and the frequency of use of each item used in each activity. The activities that require no materials are not listed on the table.

It is important to collect and organize all the materials for each minicourse before the students begin any of the activities, since the students will be working simultaneously on different activities. Having all materials readily available allows students to do the activities in the order they choose. The amount of material you will need to make available will depend on the number of lab groups that will be doing each activity. As lab groups use the "skipping option" and as they scatter themselves throughout the activities, the total amount of material needed at one time for each activity will decrease.

CONSUMABLE ITEM	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*								
	Act. 2	Act. 3	Act. 5	Act. 9	Act. 10	Act. 11	Act. 12	Act. 14	Act. 15
Copper wire, 20 cm, #40			1						

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*								
	Act. 2	Act. 3	Act. 5	Act. 9	Act. 10	Act. 11	Act. 12	Act. 14	Act. 15
Ammeter, 5-amp, DC				1		1			
Bulb socket	1		4	1	2	2			2
Circuit breaker, 5-amp			1	1	1	1			1
Circuit tester		1							
Electrical leads, 20 cm	3			2	2	2			2
Extension cord, 3-prong plug		1					1		
Knife								1	
†Lamp (or other appliance for plug repair)								1	

*A lab group is defined as one student, a pair of students, or any size group of students that you desire.

†See Advance Preparation.

NONCONSUMABLE ITEMS	MINIMUM MATERIALS PER LAB GROUP PER ACTIVITY*								
	Act. 2	Act. 3	Act. 5	Act. 9	Act. 10	Act. 11	Act. 12	Act. 14	Act. 15
Light bulb, 25-watt, 12-volt	1		2	1	1	1		2	
Light bulb, 50-watt, 12-volt			2		1	1			
Night-light, neon							1		
Pliers								1	
Pliers, cutting								1	
Plug (for appliance repair)								1	
†Power supply, 12-volt, DC	1		1	1	1	1			1
†Receptacle, 3-outlet			1	1	2	1			1
Screwdriver	1		1					1	
Switch, knife	1								
Switch, wall	1								
Thermometer −10° to 100°C			1						
†Thermostat assembly (bimetallic strip; 2 glass rods, 18 cm; tongue depressor, wooden; wire, nichrome, 40 cm)									1
Voltmeter, 15-volts, DC				1	1				
†Wire, copper #22, 20 cm			1						
†Wire, copper #32 20 cm			1						
Wire, insulated, #18, 3 m		1	1						
Resource Unit 2						✓			

*A lab group is defined as one student, a pair of students, or any size group of students that you desire.

†See Advance Preparation.

Special Safety Notes

Never plug any equipment used in this minicourse, other than the current tester and power supply, into a 110-volt outlet. Ammeters and voltmeters could be damaged by putting them in circuits supplied with more than a 12-volt DC supply. The high resistance of the circuit tester makes it safe to plug into a wall outlet.

Students have been cautioned in this minicourse to unplug the power supply while setting up equipment and adjusting connections. Plugs usually are not made to be frequently plugged in and out. To prevent students from coming in contact with "hot" wires exposed by excessive wear, caution them to hold onto the plug when they remove it from the socket. They should not just "pull" the wire. Also, check the power-supply plug from time to time to make sure the wire leading into the plug has not become frayed from frequent or improper use.

Although the procedures used in the minicourse have been tested and found safe, students should be cautioned against careless or intentional misuse of the equipment. Watch for this.

Serious injury can result from improper use of metal objects such as paper clips and pens placed onto a hot wire. Rowdy and impulsive behavior is inappropriate classroom conduct when working with laboratory apparatus.

Be sure to tell all students to keep their hands dry as they work with electricity and to be extra careful to follow directions exactly.

Advance Preparation

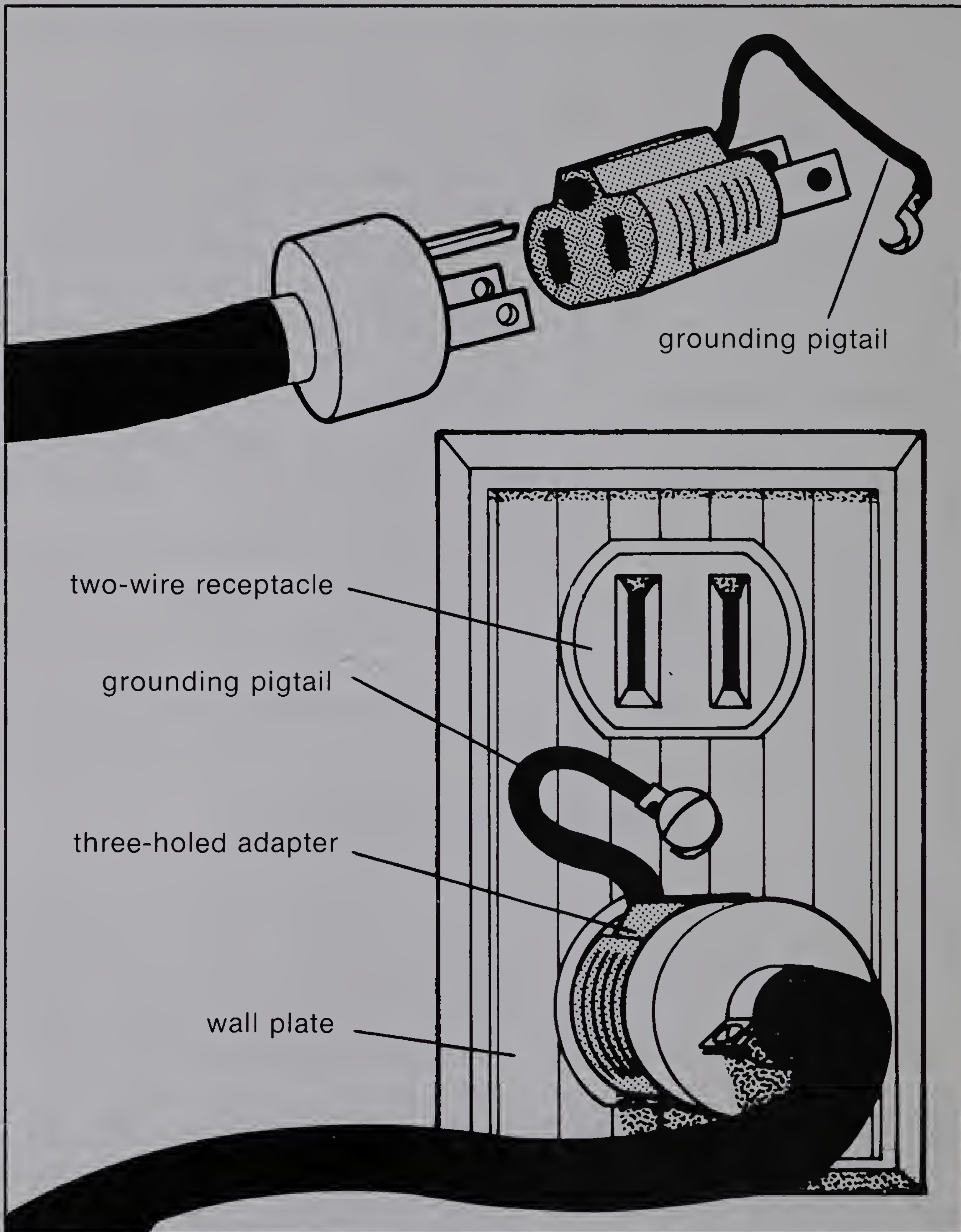
Many items for this minicourse can be borrowed or purchased locally. The physics teacher, shop teacher, and maintenance people in your school might be helpful, and a local electrical repair shop might have scraps you could use. One of your students might have a parent who is an electrician and would be willing to help.

Activities 2, 5, 9, 10, 11, 15 Pages 5, 25, 42, 47, 54, 69

For this and other activities, you'll need to set up a 12-volt power supply capable of delivering at least 5 amperes of current and of being easily and safely used by students. The variable DC sources found in many physics labs would be good. A 6-volt/12-volt battery charger is a less expensive alternative. An old car battery is also usable long after it can no longer start a car. If used, fit it in a wooden box with a 10-ampere circuit breaker mounted externally to serve as protection, and include an on/off switch at the box. The 25-watt, 12-volt light bulb is available from marine or trailor supplies. It should never be connected directly to a 110-volt outlet.

Activity 3 Core Page 14

If you don't have three-holed outlets in your room, it is best to use the circuit tester with a three-wire extension cord and a three-prong plug adapter with a pigtail. Install the adapter as shown.

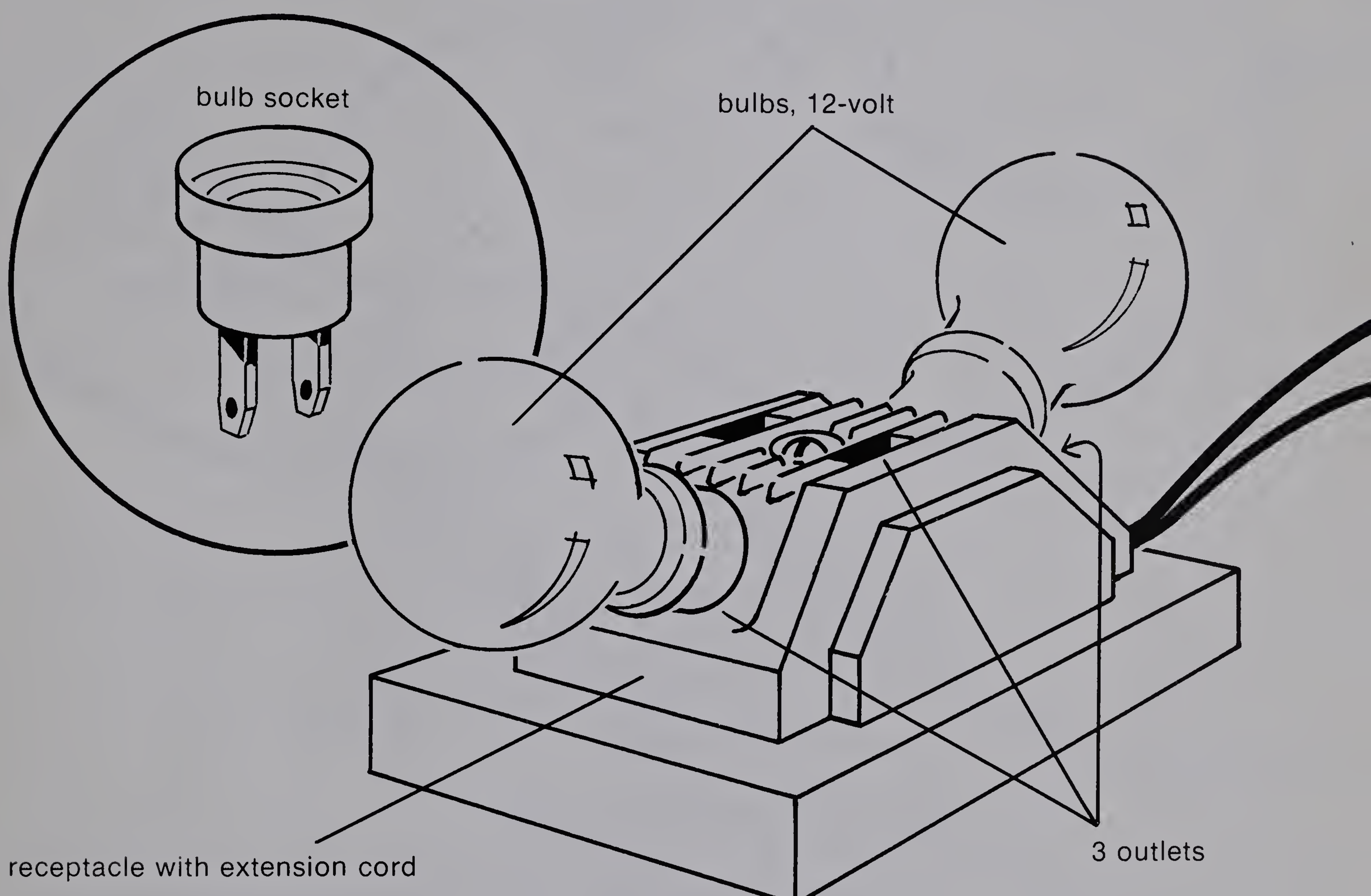


Check the grounding connection of the pigtail by using the tester. When one pin of the tester is on the grounding socket (rounded hole) of the adapter, the tester should light when its other pin is placed in one of the rectangular sockets of the adapter. And it should not light when that pin is changed to the other rectangular socket. Your students may then safely use the adapter for the investigation in Activity 3 as though it were a regular three-holed outlet.

Activity 5 Core Page 25

You will need to provide a three-outlet receptacle with two wires. The receptacle must be large enough to hold the two sockets with bulbs. Usually, the middle outlet can't be used because of the thickness of the bulbs.

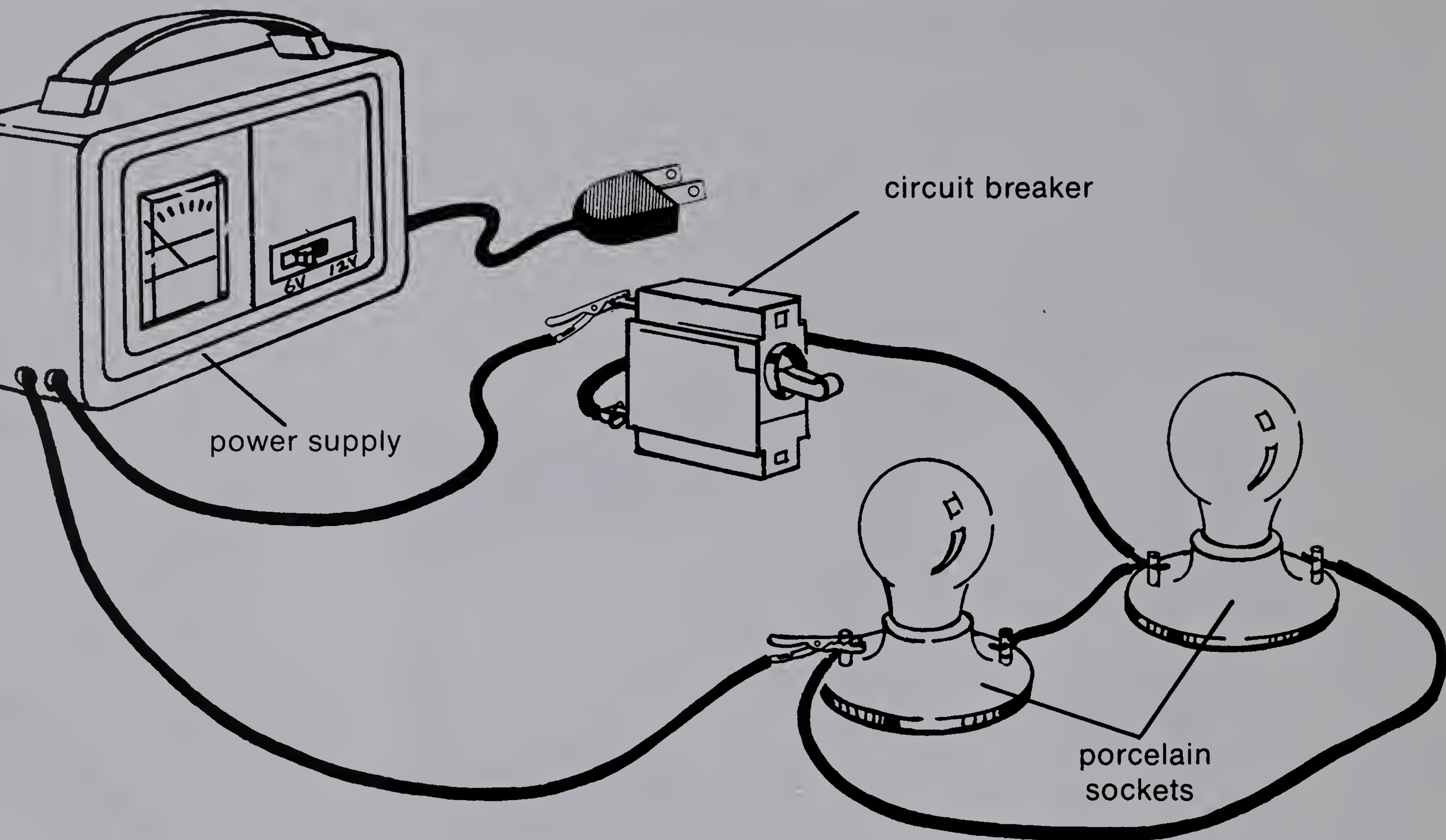
A three-outlet receptacle mounted on a wooden block will be useful throughout the minicourse. A bulb with a plug-in socket is recommended. You might also mount the knife switches on wood so students don't have to hold them down to operate the equipment.



The 50-watt, 12-volt light bulb is available from marine or trailor supplies. This bulb should never be plugged directly into a 110-volt outlet.

The three-outlet receptacle available commercially is provided with an extension cord. It is important that students gain experience in connecting bare wires to terminals. Therefore, you will want to cut the cord to leave about 60 cm connected to the receptacle. Then separate the two wires for about 45 cm. Leave 2 cm of each wire bare.

As an alternative to the bulb-extension cord apparatus, you could use free-standing porcelain sockets, connected in parallel to the power supply and circuit breaker as shown.



With reference to wires #22, 32, and #40, if you don't have or don't know the exact wire sizes, you may wish to try out what you do have ahead of time. You can then label your wire simply (thick, thinner, thinnest) and give revised directions to the students.

You may wish to collect examples of various sizes and types of fuses and circuit breakers for your students to examine.

Activity 6 Core Page 32

A local electrician may be able to supply examples of the various plugs and receptacles to illustrate different circuit requirements.

Activity 7 Core Page 36

The police, fire department, or a hospital in your area may be able to provide a resuscitation "dummy" to use in class.

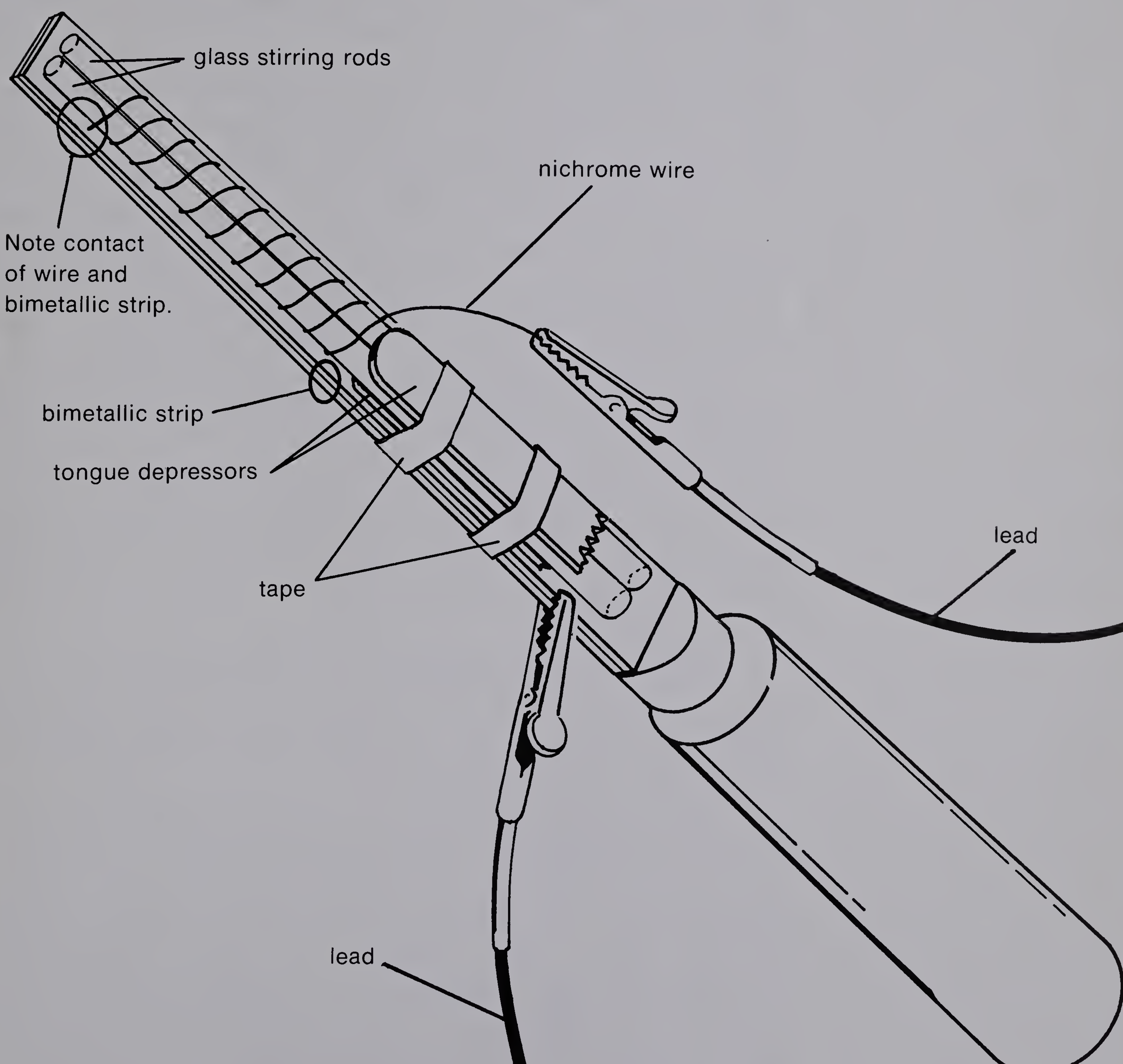
Activity 14 Excursion Page 64

Collect appliances with frayed cords from around the school and ask students to bring them from home. If necessary, the same cord could be repaired repeatedly by cutting off the existing plug for each use.

Activity 15 Excursion Page 69

It is suggested that you (or the first students who do the activity) construct the thermostat assembly as shown so that it may be used intact by the (other) students. You will need:

bimetallic strip with handle
2 glass stirring rods, each as long as the bimetallic strip
wooden tongue depressor
nichrome wire, 40 cm, #24
tape



Make about 15 turns of the nichrome wire around one-half the length of the glass rods. Break the tongue depressor in two and tape one half above and the other half below the glass rods. Heat the bimetallic strip to see which way it bends. Tape the tongue depressor portion to the bimetallic strip near the handle. Bend the last turn of the nichrome wire so that it makes contact with the bimetallic strip. This should be the only point of contact between the wire and the metal strip.

Background Information

The following information can be of use throughout the minicourse and should aid in overall understanding.

When a two-holed receptacle or wall outlet is in use, electricity can be thought of as coming out of one slot (the hot side), passing through the appliance (lamp, toaster, refrigerator, etc.), and returning through the other slot (the neutral side). A circuit tester can be used to determine which side is hot.

If the insulation on the hot wire fails and the wire touches the outside case of an appliance, the appliance becomes hot and would shock you if you touched it. Your body would complete a circuit from the hot wire through the appliance case and you to the ground.

When a three-holed receptacle or wall outlet is in use, a third wire (through the round hole) connects the appliance case directly to the ground. But there is no current in the third wire unless the appliance case is hot—unless there is full or partial short circuit. In the case of a full short, the circuit breaker or fuse would immediately trip or blow. With a partial short, you could touch the hot appliance and not be shocked because the electricity flows from the hot wire through the appliance case and third wire to ground, rather than through you to ground.

A water pump analogy to electric circuits is used extensively in the activities. The comparison is an old common one, but the mistakes associated with its use are frequent. In particular, avoid the notion that voltage pushes. The power supply pushes; voltage is the measure of the strength of the push.

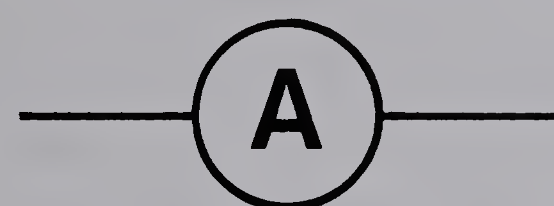
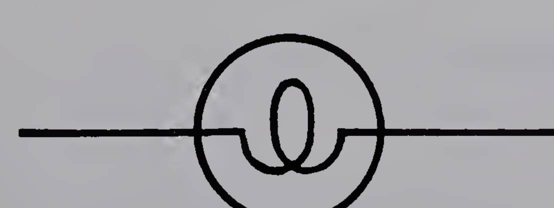
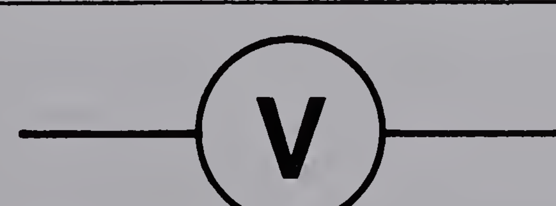
Consistent use of the term *neutral* to describe the ground-return wire will keep it distinct from the grounding wire of a three-wire cord.

Current direction is (1) from high potential to low in any circuit in which energy is being used, and (2) from low potential to high inside a power supply. This agrees with the definition of *current* as the time rate of flow of charge. The definition contains no negative sign, so positive charge is implied. In this minicourse, the sign of the electron is never mentioned, so there is no need to go into the question of the direction of motion of the electrons.

Resistance is a property of a conductor, the ratio of potential difference (PD) across it to current (I) in it. The equation $R = V$ is a definition of *resistance*. Ohm's Law states that R is constant for a metallic conductor at constant temperature.

Avoid the concept that more heat is produced by nichrome because it has more resistance than copper. That is not true. At fixed potential difference, the rate of heat production is V^2/R—the more resistance, the less heat. Nichrome has a higher resistivity than copper, so the wire can be thicker for any desired value of resistance. This makes the wire mechanically stronger. Also, it has a higher melting point and will not oxidize.

The following standard circuit symbols are used in several advanced activities.

ammeter	
battery (power supply)	
circuit breaker	
conductor	
lamp	
voltmeter	

Evaluation Suggestions

In addition to the minicourse test, you might use some or all of the following suggestions to evaluate your students.

Essay Questions

Two essay suggestions and their model answers follow. Both questions are related to core materials.

1. Explain how the demand for increasing human safety has made it necessary to change household wiring.

Answer: Not many years ago, most houses were wired with a 110-volt circuit. A 110-volt circuit supplied the current requirments of the then few household appliances. Today, many houses also have 220-volt circuits. The standard of living has gone up and so have the family's comfort requirements for electrically run gadgets.

To supply the many new appliances being used in homes today, more 110-volt branch circuits, such as single-appliance circuits, appliance circuits, and general-purpose circuits, had to be added.

2. What first-aid steps would you take to help someone who has suffered a severe electric shock?

Answer:

a. Think! Don't do anything to endanger your life.
b. If possible, shut off the electricity.
c. If you can't shut off the electricity, move the victim away from the electric lines with a wooden pole or move the electrical lines away from the victim with the wooden pole.
d. If the victim is unconscious and not breathing, administer artificial respiration.
e. Send someone to call a physician and an ambulance.
f. Cover the victim, and try to keep him or her quiet until the arrival of the physician or ambulance.

Laboratory Performance

Activity 14 provides an opportunity to evaluate student performance. The student is asked to repair a frayed plug. You may wish to observe students repair a plug after they have used the activity for practice.

Activities 9 and 10 have objectives that ask students to measure voltage and current. You may wish to observe students as to whether or not they correctly connect and read voltmeters and ammeters.

References

Editors of Time-Life Books. 1975. *How things work in the home (and what to do when they don't).* Family Library. New York: Time-Life Books.

Helpful illustrations and text explain how things work. The chapter on electricity helps take the guesswork out of home wiring and enables the lay person to do many electrical jobs safely and efficiently.

Gerrish, H. H. 1971. *Exploring electronics.* South Holland, Illinois: The Goodheart-Wilcox Co., Inc.

Photographs in the text add to the discussion about definitions, concepts, and applications. Lab work is infrequent and is tailored to a separate kit.

Noll, E. M. 1965. *Science projects in electricity.* Indianapolis: Bobbs-Merrill Co., Inc.

This book describes similar experiments presented in this minicourse, as well as many other concepts.

Richter, H. P. 1975. *Wiring simplified.* St. Paul: Park Publishing, Inc.

A very readable introduction to all aspects of home electricity. It is revised every three or four years based on the revised *National Electrical Code.*

Steinberg, W. F., and Ford, W. B. 1972. *Electricity and electronics: Basic.* 4th ed. Chicago: American Technical Society.

Aimed at early high school, this book delves deeper into theory than does ISIS and goes into communication applications of electricity. However, most of the book deals with topics covered in this minicourse, and it suggests many activities.

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acknowledgments

In addition to the major effort by the ISIS permanent staff, writing conference participants, and author-consultants (listed on the inside of the back cover), the following contributed to this minicourse.

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foreword

Evidence has been mounting that something is missing from secondary science teaching. More and more, students are rejecting science courses and turning to subjects that they consider to be more practical or significant. Numerous high school science teachers have concluded that what they are now teaching is appropriate for only a limited number of their students.

As their concern has mounted, many science teachers have tried to find instructional materials that encompass more appropriate content and that allow them to work individually with students who have different needs and talents. For the most part, this search has been frustrating because presently such materials are difficult, if not impossible, to find.

The Individualized Science Instructional System (ISIS) project was organized to produce an alternative for those teachers who are dissatisfied with current secondary science textbooks. Consequently, the content of the ISIS materials is unconventional as is the individualized teaching method that is built into them. In contrast with many current science texts which aim to "cover science," ISIS has tried to be selective and to limit our coverage to the topics that we judge will be most useful to today's students.

Obviously the needs and problems of individual schools and students vary widely. To accommodate the differences, ISIS decided against producing tightly structured, pre-sequenced textbooks. Instead we are generating short, self-contained modules that cover a wide range of topics. The modules can be clustered into many types of courses, and we hope that teachers and administrators will utilize this flexibility to tailor-make curricula that are responsive to local needs and conditions.

ISIS is a cooperative effort involving many individuals and agencies. More than 75 scientists and educators have helped to generate the materials, and hundreds of teachers and thousands of students have been involved in the project's nationwide testing program. All of the ISIS endeavors have been supported by generous grants from the National Science Foundation. We hope that ISIS users will conclude that these large investments of time, money, and effort have been worthwhile.

Ernest Burkman

Ernest Burkman
ISIS Project Tallahassee, Florida

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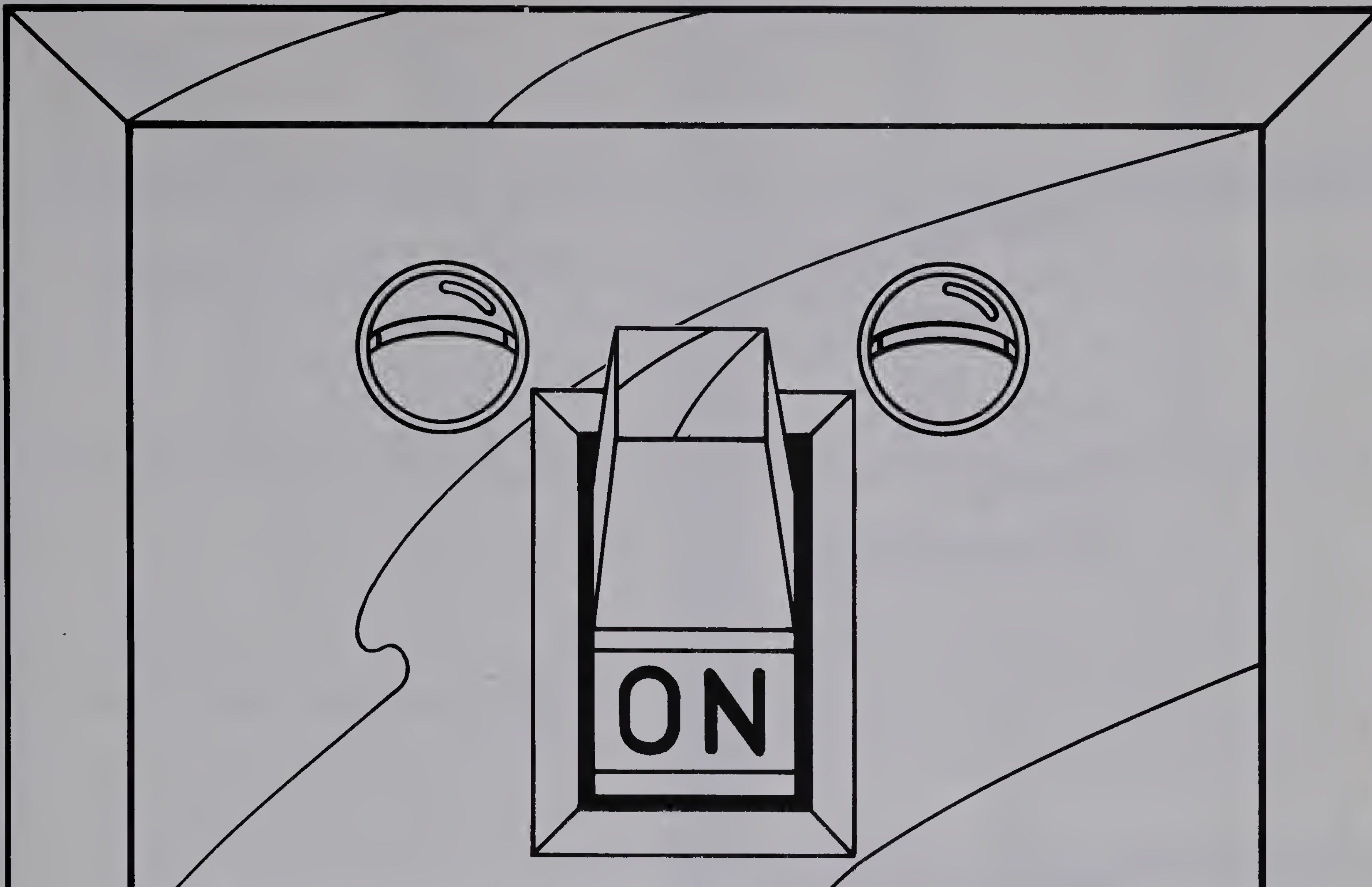
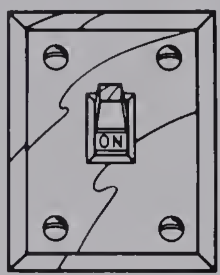


What's It All About?

Believe it or not, you're the boss of hundreds of "workers" every day. And they'll give you no back talk. You're the boss. Just flip the switch. That's the command.

But maybe you need to know more about your workers and how to handle their needs. That's what this mini-course is about. The activities help you learn about the wiring in your home. They also show you special safety features and what to do if they fail. You'll construct simple circuits and do basic calculations and electrical repairs.

When you're finished, you'll have a better understanding of and respect for electrical energy.



Activity 1 Core Planning

If you need to do Activity 2, do it first. If you need to do Activity 5, do it before Activity 6. The other activities may be done in any order.

Activity 2 Page 5

Objective 2–1: Describe the function in an electric circuit of the power supply, conductors, insulators, switches, and lamps by comparing them to a system in which water flows through pipes.

Sample Question: The function of a lamp in an electrical circuit can be compared to which component of a water system?

a. valve
b. narrowing in pipes
c. water pump
d. water

Objective 2–2: Describe voltage and current in terms of water flowing through pipes.

Sample Question: Match each term with the appropriate statement.

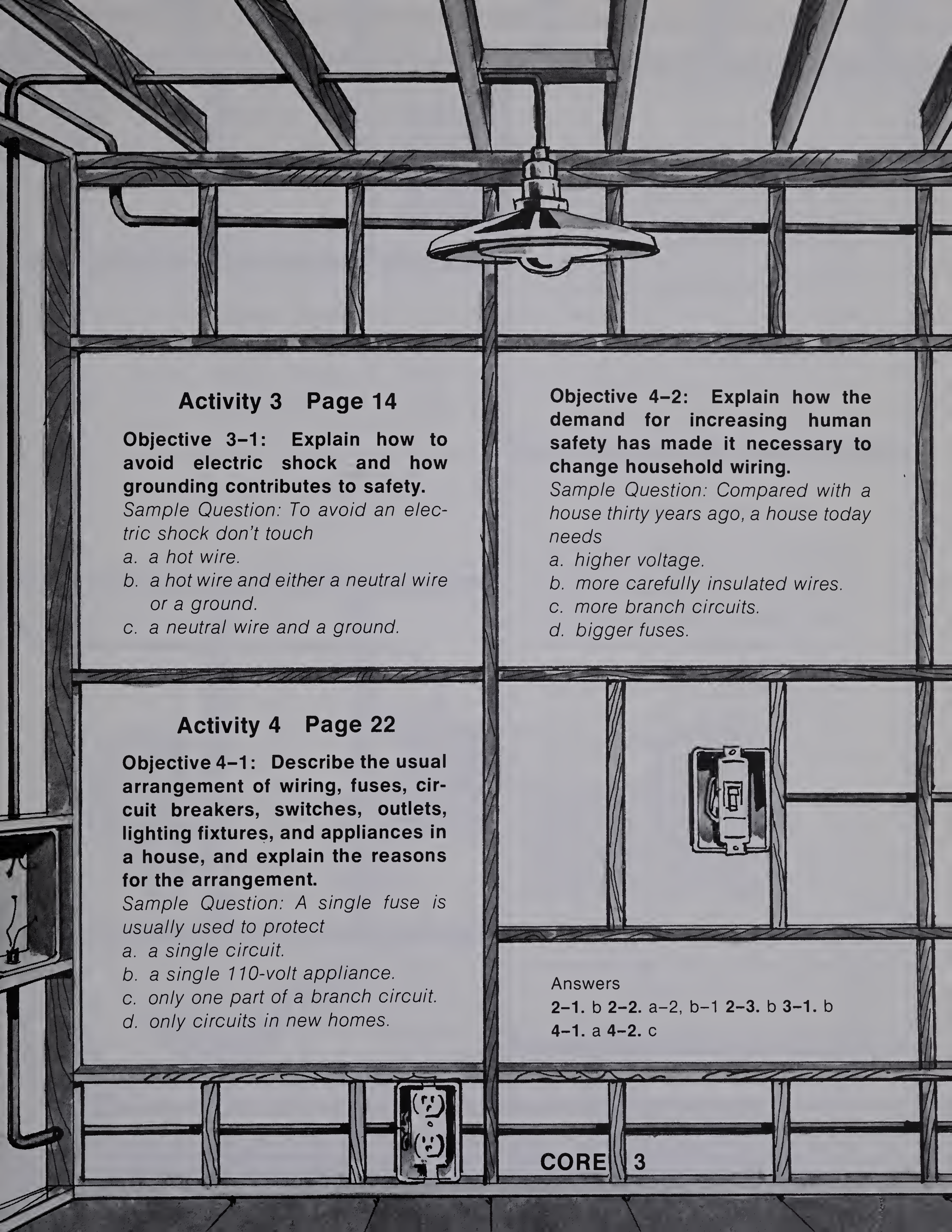
Term
a. current
b. voltage

Statement
1. pressure
2. rate of flow
3. amount of water
4. width of pipe

Objective 2–3: Describe an electric current in a wire in terms of moving electrons, and the units in which it is measured.

Sample Question: Electrons will flow through a circuit when the circuit's two terminals are

a. insulated.
b. connected to points having a voltage difference.
c. connected to the same terminal of a power supply.
d. at very different temperatures.



Activity 3 Page 14

Objective 3–1: Explain how to avoid electric shock and how grounding contributes to safety.

Sample Question: To avoid an electric shock don't touch

a. a hot wire.

b. a hot wire and either a neutral wire or a ground.

c. a neutral wire and a ground.

Activity 4 Page 22

Objective 4–1: Describe the usual arrangement of wiring, fuses, circuit breakers, switches, outlets, lighting fixtures, and appliances in a house, and explain the reasons for the arrangement.

Sample Question: A single fuse is usually used to protect

a. a single circuit.

b. a single 110-volt appliance.

c. only one part of a branch circuit.

d. only circuits in new homes.

Objective 4–2: Explain how the demand for increasing human safety has made it necessary to change household wiring.

Sample Question: Compared with a house thirty years ago, a house today needs

a. higher voltage.

b. more carefully insulated wires.

c. more branch circuits.

d. bigger fuses.

Answers

2–1. b **2–2.** a–2, b–1 **2–3.** b **3–1.** b **4–1.** a **4–2.** c

Activity 5 Page 25

Objective 5–1: Explain how wire size limits the kind and number of appliances that can be used on a single branch circuit and how the wiring is protected against overload.

Sample Question: What two things may happen to a wire if it is too thin for the amount of current in it?

Activity 6 Page 32

Objective 6–1: Examine the voltage, power, and frequency ratings on the labels of household appliances, calculate the current they use, and determine which circuits to use them in.

Sample Question: How much current is drawn when an electric iron rated at 110 volts, 1100 watts is being used?

Objective 6–2: Use ratings of several appliances to determine whether a given branch circuit has enough current capacity.

Sample Question: A 110-volt circuit in a home has a 20-ampere fuse. Connected on that branch circuit are five 100-watt bulbs and a 1100-watt heater. Will the fuse blow?

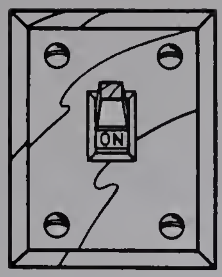
Activity 7 Page 36

Objective 7–1: Describe the effects of severe electric shock, and tell how to deal with it.

Sample Question: Two main causes of death by electric shock are

a. heart failure.
b. lung failure.
c. burning of the body.
d. fright.

Answers
5–1. gets hot and breaks **6–1.** 10 amperes **6–2.** no **7–1.** a and b



Activity 2
Turned-On Circuits

ACTIVITY EMPHASIS: The parts of an electrical circuit are compared with the parts of a water system. Voltage and current are also related to the water system. Electricity is then described in terms of moving electrons.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.
See also Advance Preparation, p. TM 5.

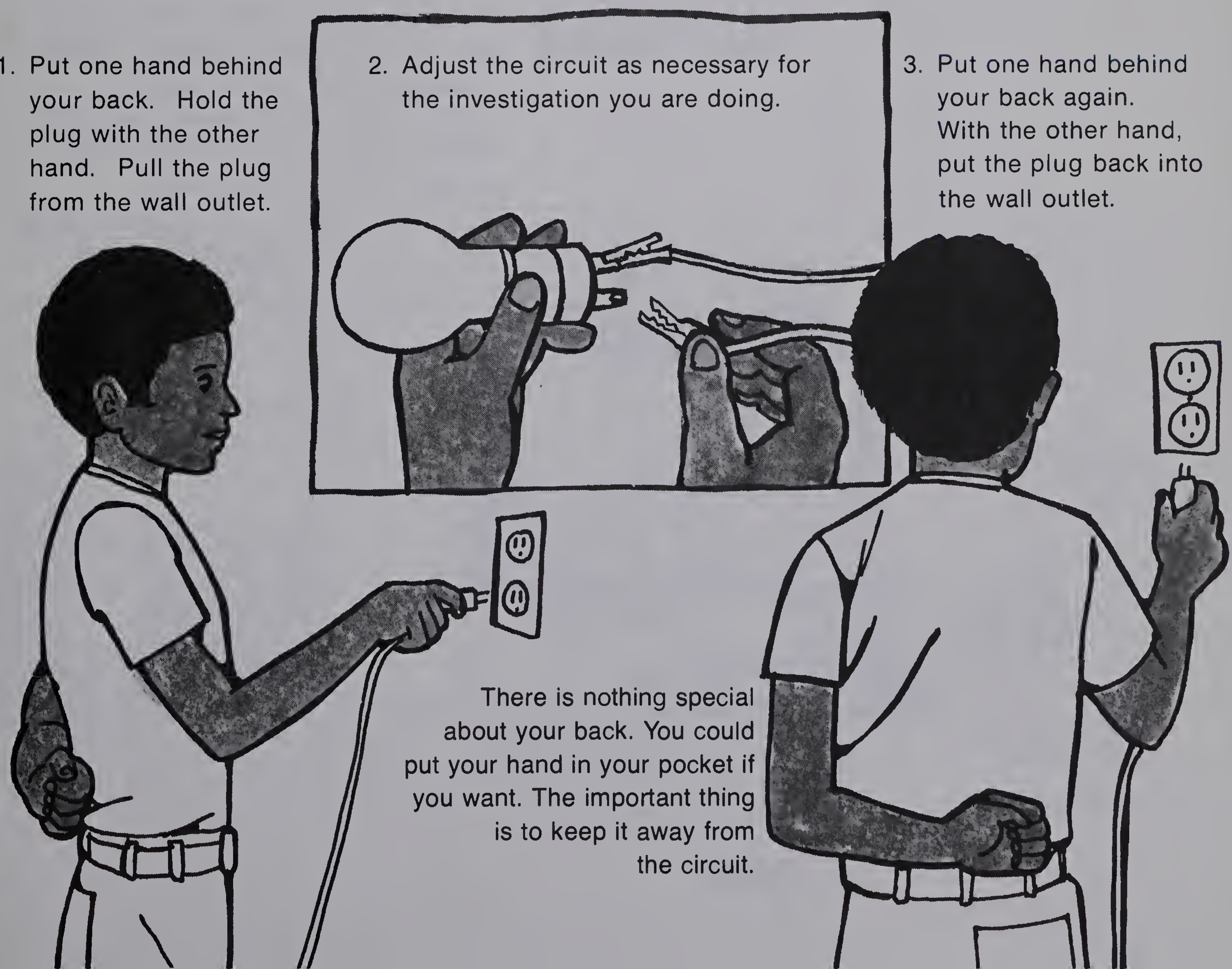
When no one is around, that lamp in your room just sits there. It does nothing but take up space. You come in and throw a switch. Suddenly the lamp floods the room with light. What happened?

To find out, you will work with real lamps and switches. But before you get them, here are three safety rules for you to read, remember, and follow throughout this minicourse.

SAFETY RULE: Be sure your hands are dry when working with electricity.

SAFETY RULE: Don't touch any of the metal parts of a circuit while the plug is in the wall unless you are told to in the instructions. Here's one way to remember to do that.

1. Put one hand behind your back. Hold the plug with the other hand. Pull the plug from the wall outlet.
2. Adjust the circuit as necessary for the investigation you are doing.
3. Put one hand behind your back again. With the other hand, put the plug back into the wall outlet.



There is nothing special about your back. You could put your hand in your pocket if you want. The important thing is to keep it away from the circuit.

If you are not able to unplug your power supply, here's another safety rule for you.

SAFETY RULE: If your power supply can't be unplugged, make sure it is turned off before you work on a circuit. Turn it on again only after everything is set.

• 2–1. If you follow the safety rules, what keeps you from touching any metal parts of the circuit when you handle the plug?

2-1. Put one hand behind your back or in your pocket when connecting or unplugging the power supply.

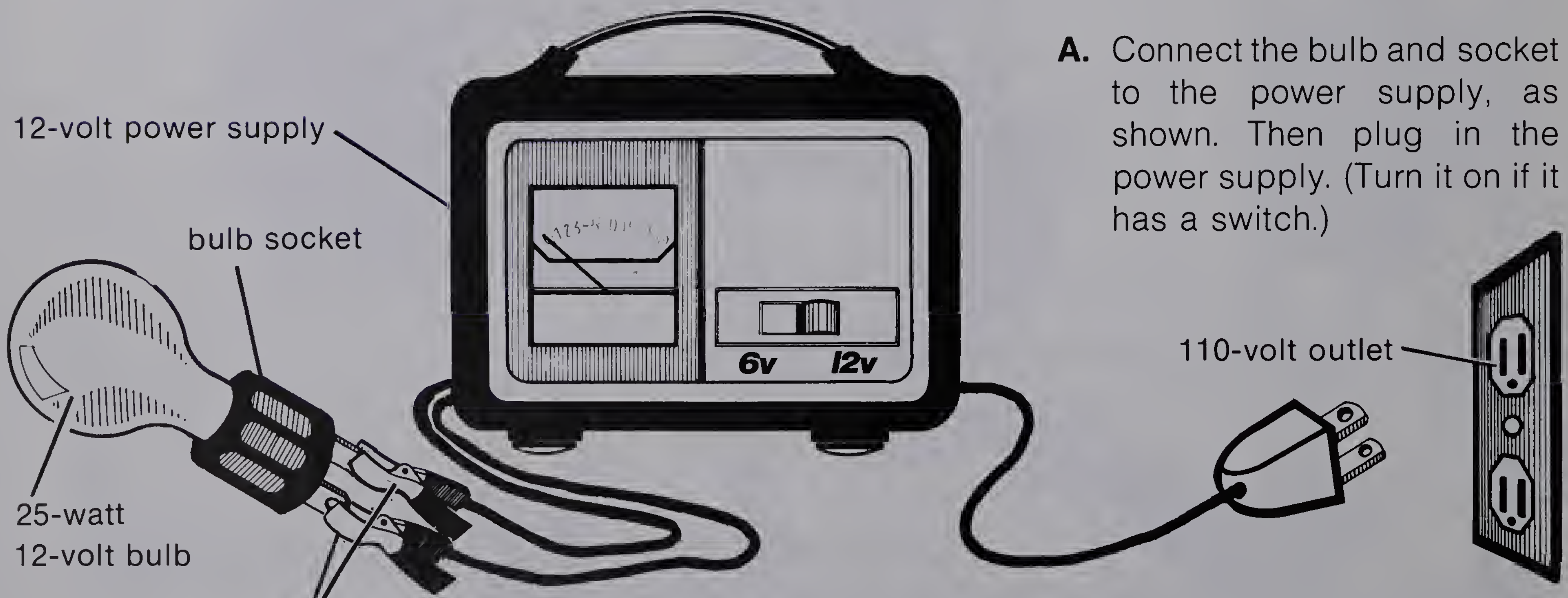
Here's the list of materials you'll need:

bulb, 25-watt, 12-volt
bulb socket
power supply (or battery charger) 12-volt
3 lengths of wire called *leads*, 20 cm each
knife switch
wall switch
screwdriver

CAUTION **Don't plug the bulb and socket into any 110-volt outlet. It will instantly burn out the bulb.**

Be sure your hands are dry when plugging anything into a circuit carrying electricity.

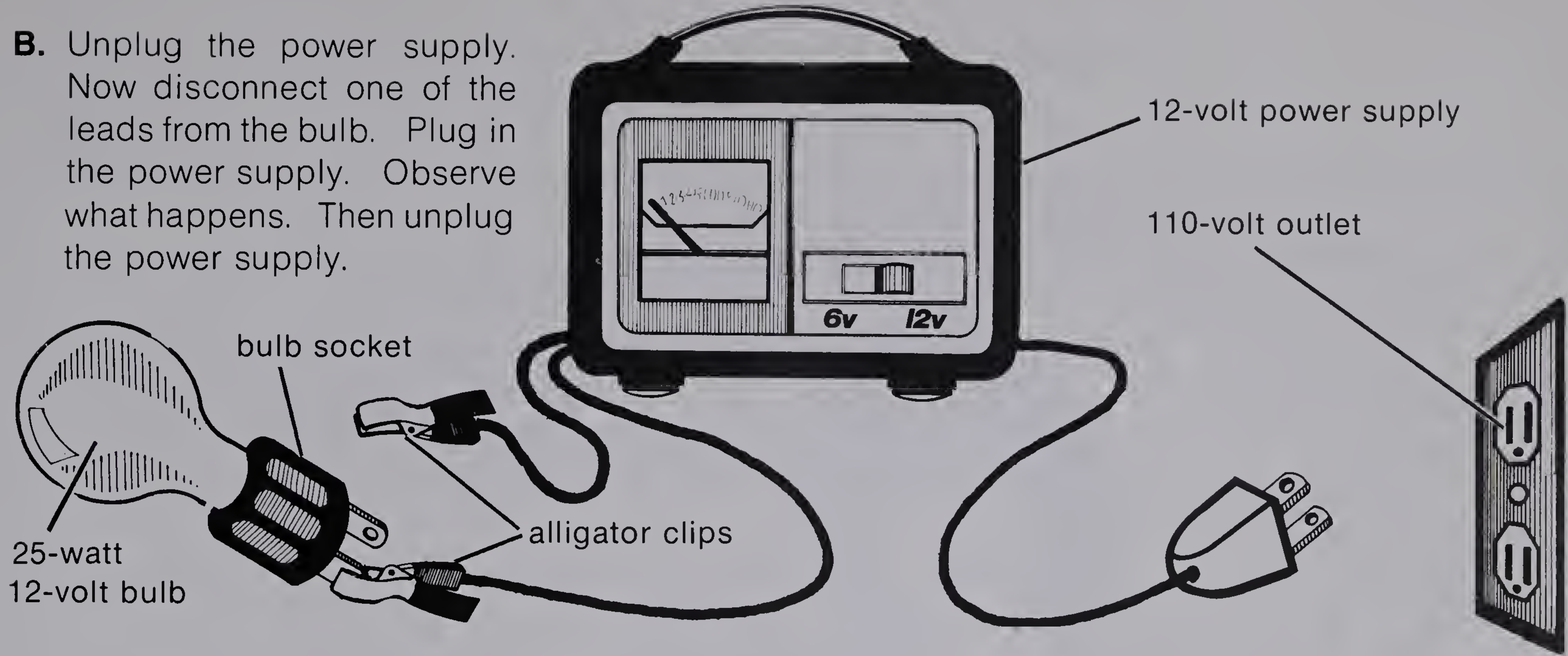
A. Connect the bulb and socket to the power supply, as shown. Then plug in the power supply. (Turn it on if it has a switch.)



• 2–2. What happens when you plug the power supply in or turn on the switch?

2-2. The bulb lights.

B. Unplug the power supply. Now disconnect one of the leads from the bulb. Plug in the power supply. Observe what happens. Then unplug the power supply.



- 2–3. What happens when you plug the power supply in or turn on the switch?

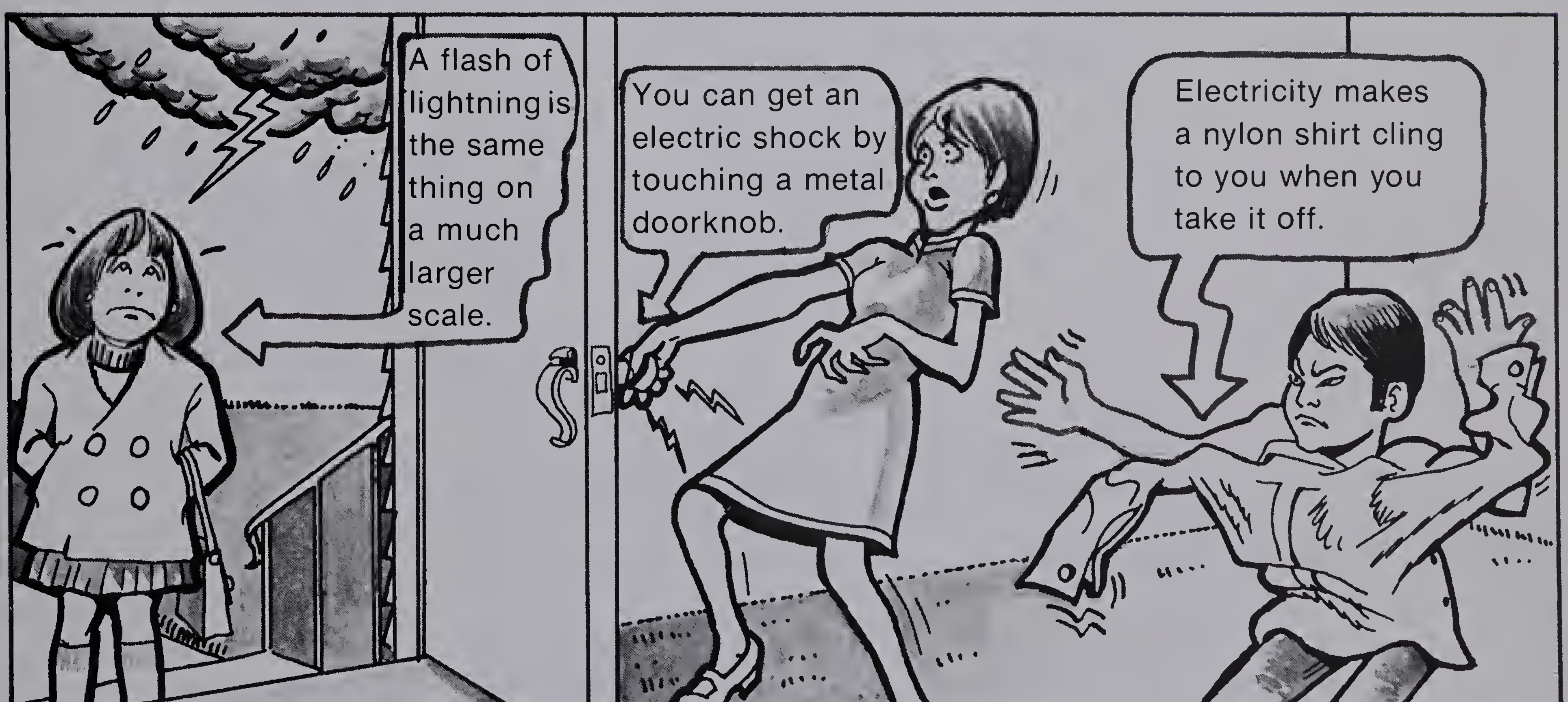
2-3. The bulb does not light.

- 2–4. How many wires must be connected to the bulb to make it light?

2-4. 2 wires

To get electricity to flow through the bulb, certain things are needed. That's not because electricity is something unusual. In fact, it is in everything though you can't always see its effects.

If you want electricity to light a bulb, you have to make it flow through the bulb.



- 2–5. Through what does electricity flow to make the bulb light?

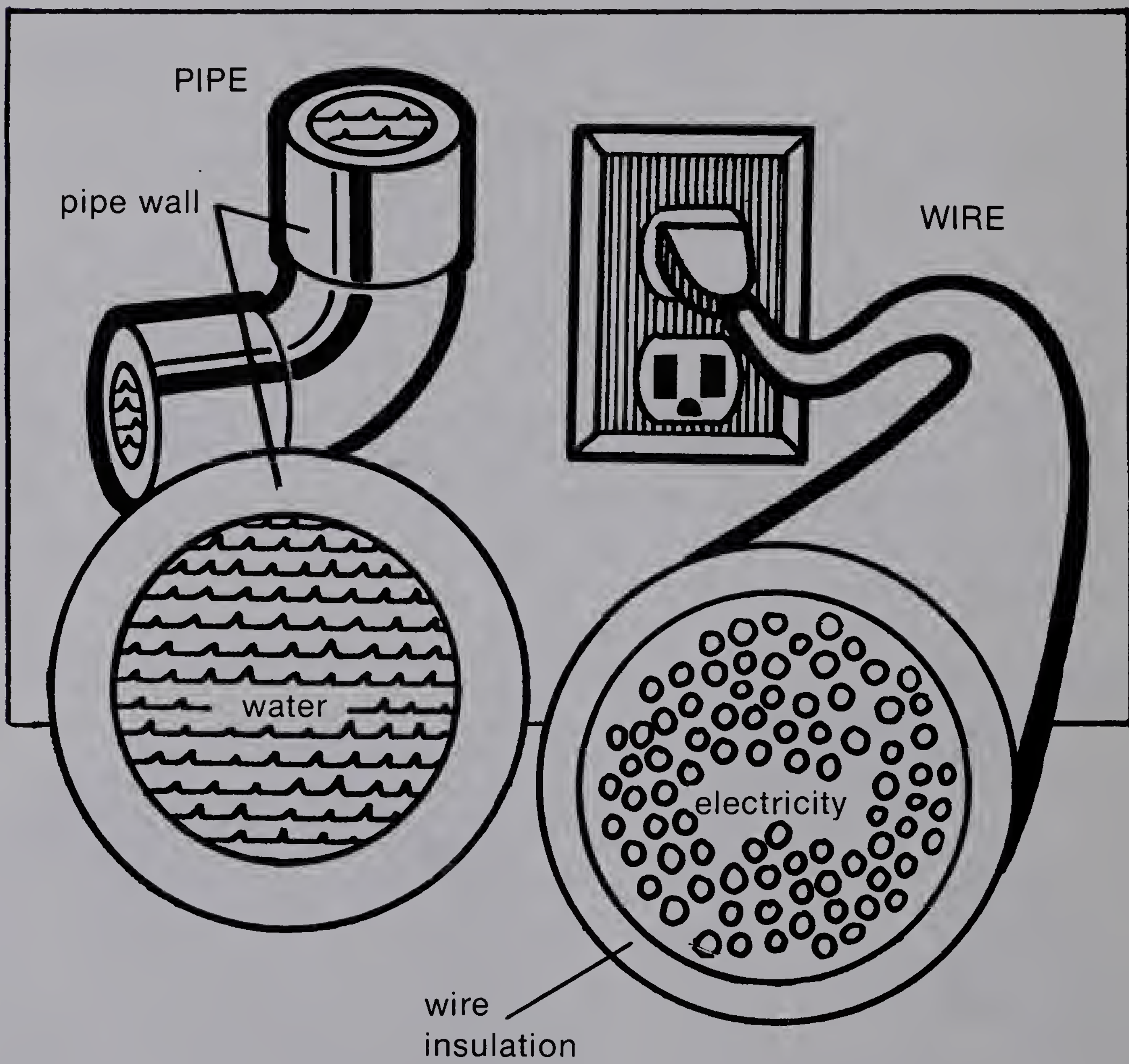
2-5. Wires.

Any material that allows electricity to flow through it easily is called a *conductor*. Metals are good conductors. Materials that do not allow electricity to flow are called *insulators*. Rubber, plastic, glass, and air are all good insulators.

2-6. Metals are good conductors.

• 2–6. Why are wires made of metal rather than plastic?

In some ways, electricity flowing through a wire is like water flowing through a pipe. The insulation around a wire is like the wall of a pipe. The pipe's wall keeps the water inside. The insulation around a wire keeps the electricity from getting out.



2-7. To prevent the wires from touching some other conductor, and thereby shorting the circuit.

• 2–7. Air is a good insulator. Why do you think the wires in your home need rubber or plastic insulation around them anyway?

Suppose you have a pipe full of water. The water will not flow if a valve in the pipe is shut off or if the pipe is capped. In the same way, electricity will not flow if a switch is not on, or a wire is disconnected.

Just what is it that flows through a wire in the way water flows through a pipe? Take a look at Figure 2–1.

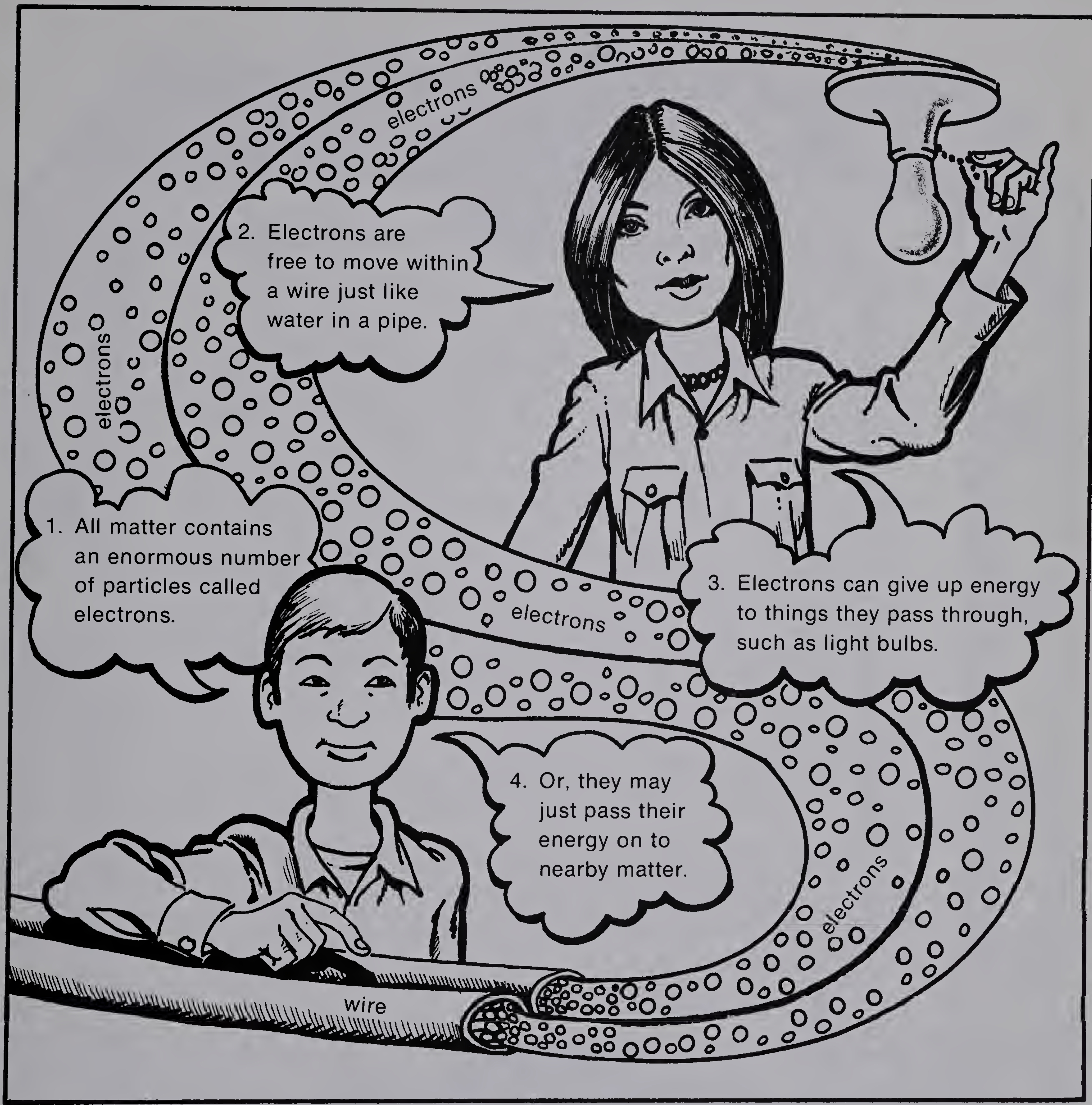
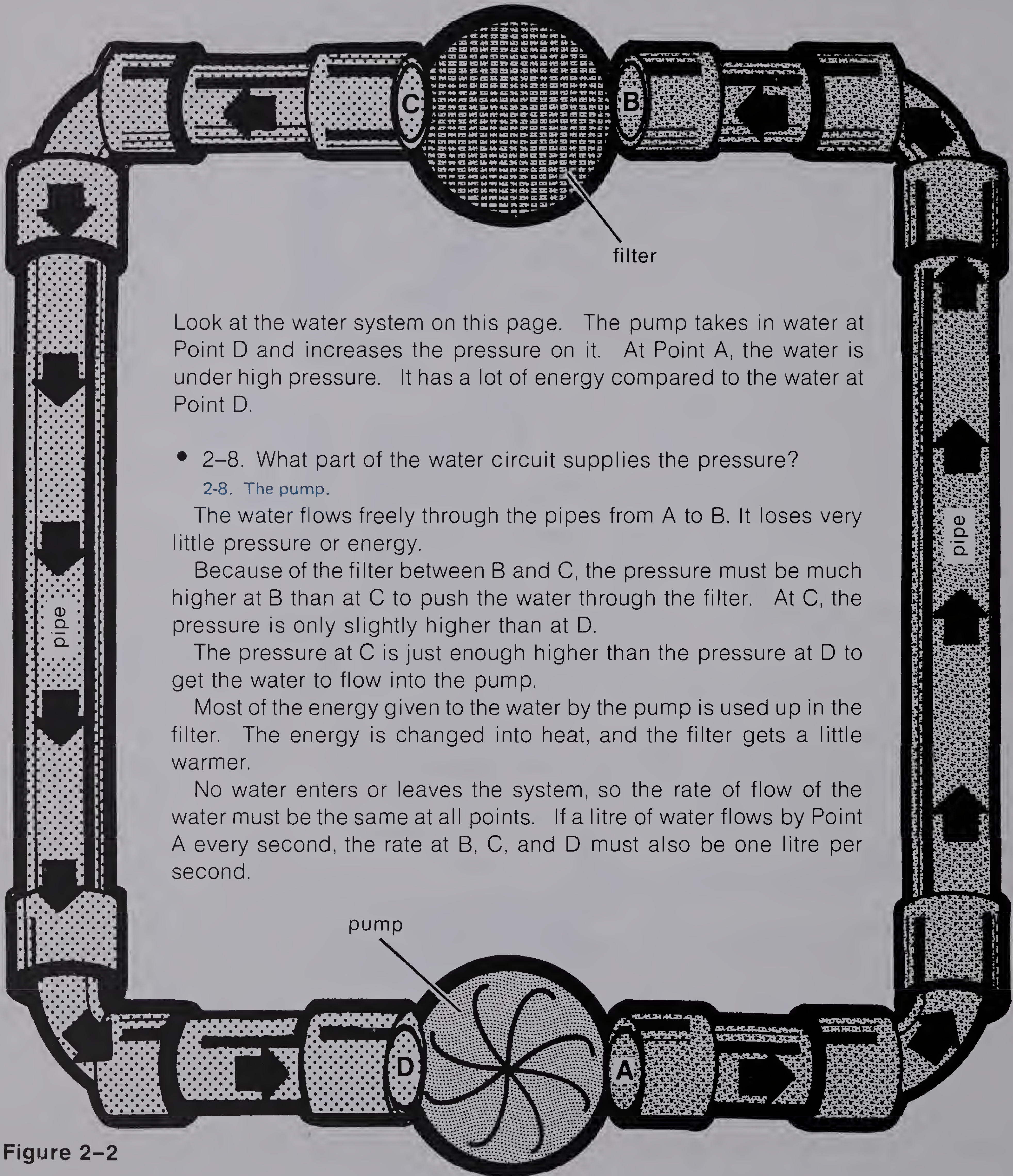


Figure 2–1

Compare the electric circuit you made with a similar arrangement of water in a closed system of pipes. Page 10 explains the water system. Page 11 shows you about electricity.

A Water System Compared



Look at the water system on this page. The pump takes in water at Point D and increases the pressure on it. At Point A, the water is under high pressure. It has a lot of energy compared to the water at Point D.

- 2–8. What part of the water circuit supplies the pressure?

  2-8. The pump.

The water flows freely through the pipes from A to B. It loses very little pressure or energy.

Because of the filter between B and C, the pressure must be much higher at B than at C to push the water through the filter. At C, the pressure is only slightly higher than at D.

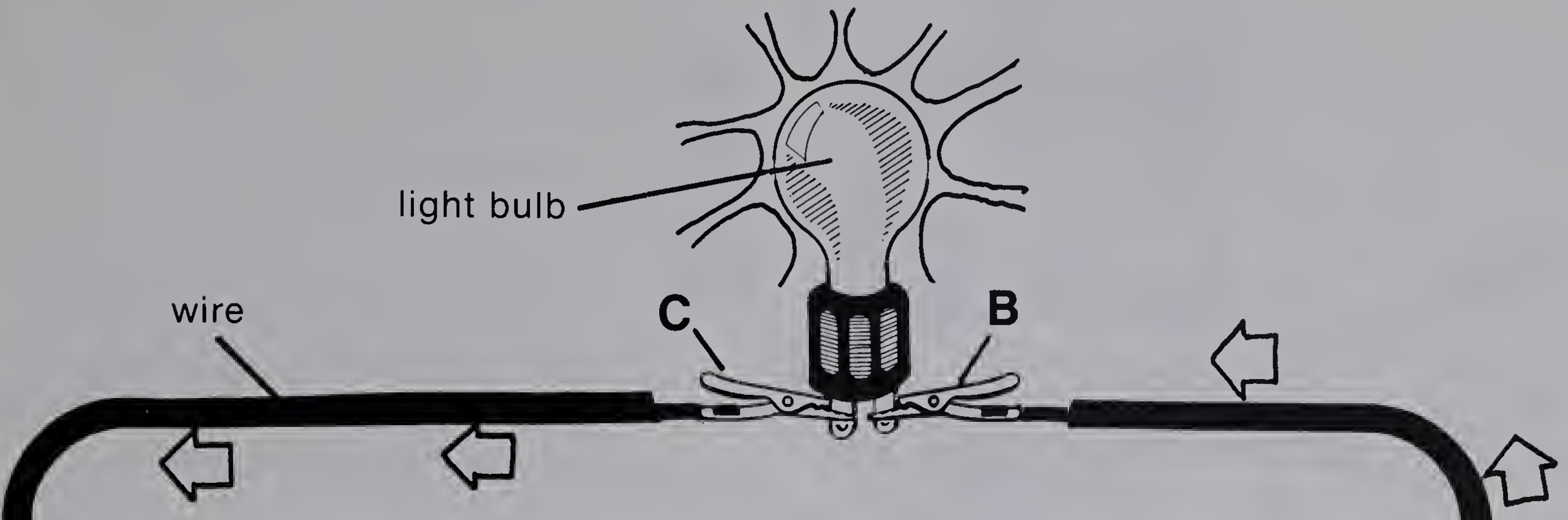
The pressure at C is just enough higher than the pressure at D to get the water to flow into the pump.

Most of the energy given to the water by the pump is used up in the filter. The energy is changed into heat, and the filter gets a little warmer.

No water enters or leaves the system, so the rate of flow of the water must be the same at all points. If a litre of water flows by Point A every second, the rate at B, C, and D must also be one litre per second.

Figure 2–2

o an Electrical System



Look at the electrical system on this page. The power supply causes the electrical pressure (voltage) at Points A and D to be different. At Point A the electrons have a lot of energy compared to those at Point D.

- 2–9. What part of the electric circuit supplies the pressure (voltage)? 2-9. The power supply.

The electrons flow freely through the wire from A to B. The voltage and energy change very little.

Because of the light bulb between B and C, there must be a voltage difference between B and C to cause the electrons to flow through the bulb. At C, the voltage is only slightly different from the voltage at D.

- 2–10. If the voltage at C is just enough higher than the voltage at D, in what direction will the electrons flow?
  2-10. Back to the power supply.

Most of the energy given to the electrons by the power supply is used up in the light bulb. The energy is changed into heat and light.

No electrons can enter or leave the system, so the rate of flow of electrons must be the same at all points. This rate of flow of electrons determines the *electric current*. Electric current is measured in units called *amperes*.

- 2–11. If the current leaving the power supply at Point A is 3 amperes, what will be the current leaving the bulb at Point C? 2-11. 3 amperes

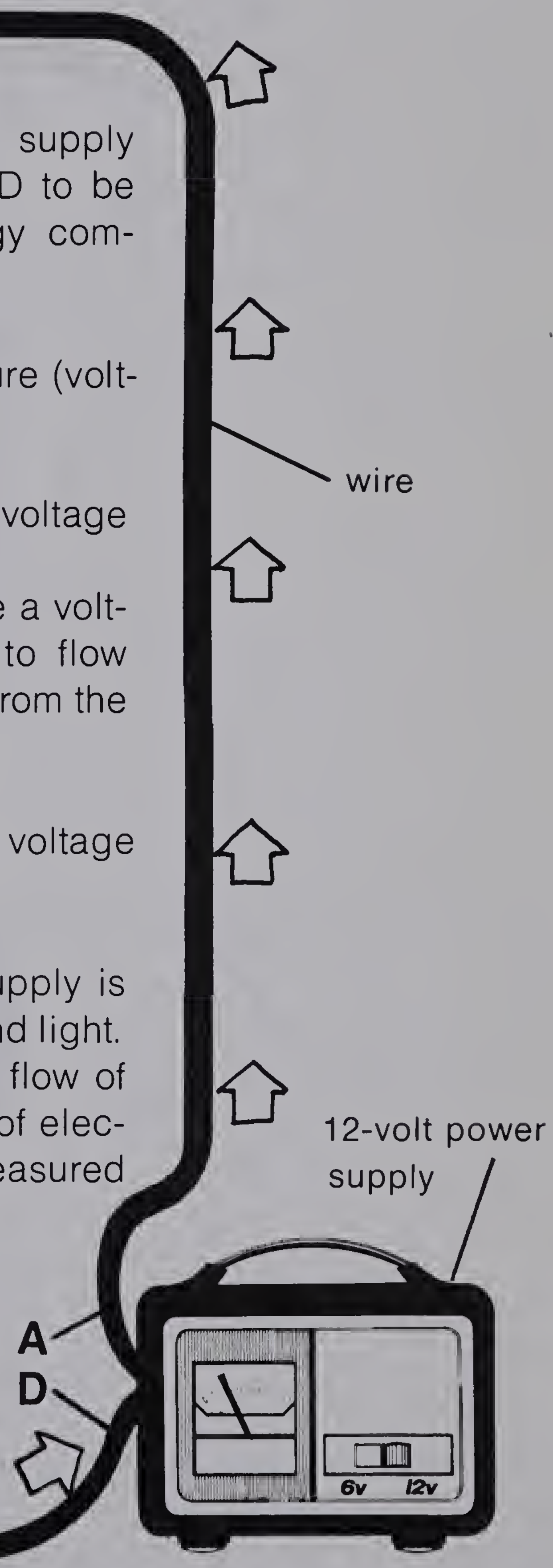
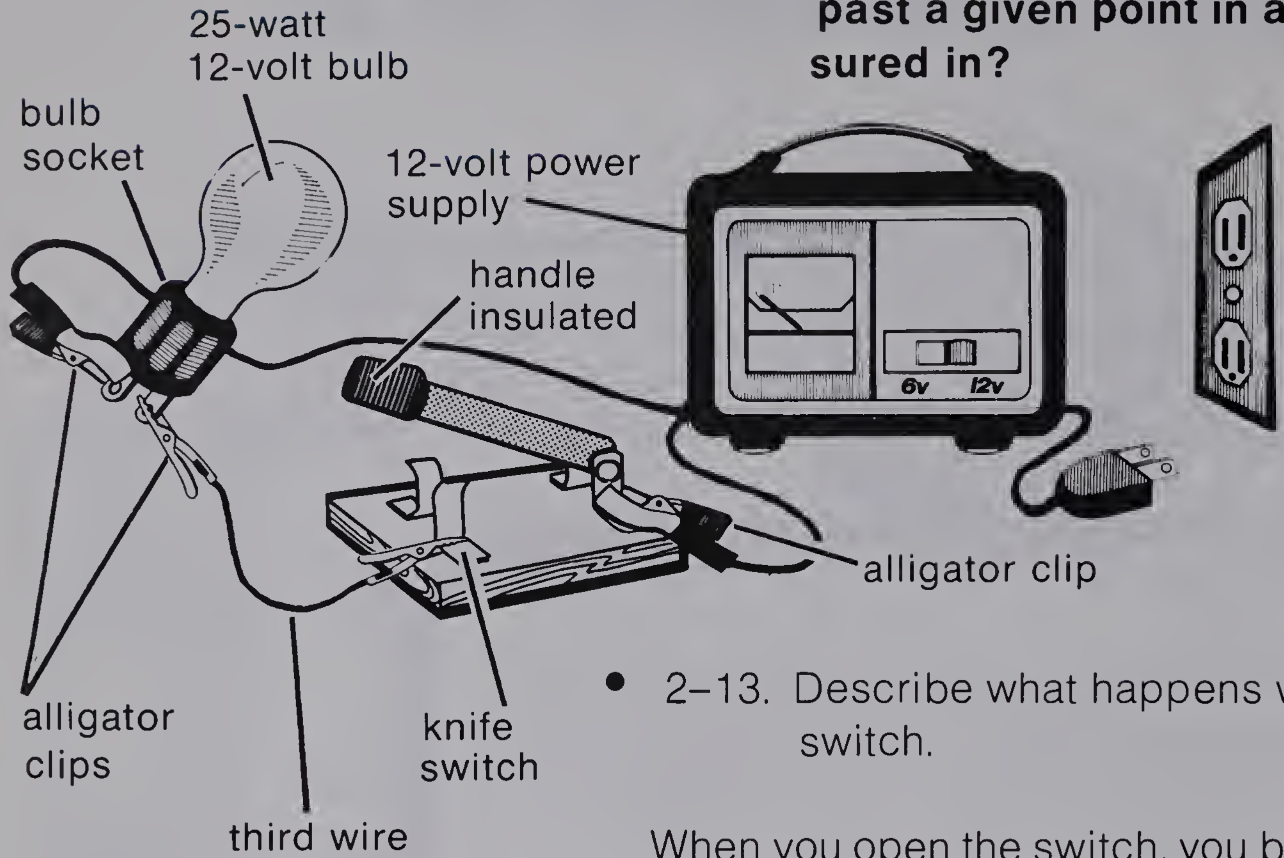


Figure 2–3

2-12. (a) Current; (b) amperes.

★ **2–12. What term describes the rate at which electrons flow past a given point in a circuit? What unit is that measured in?**

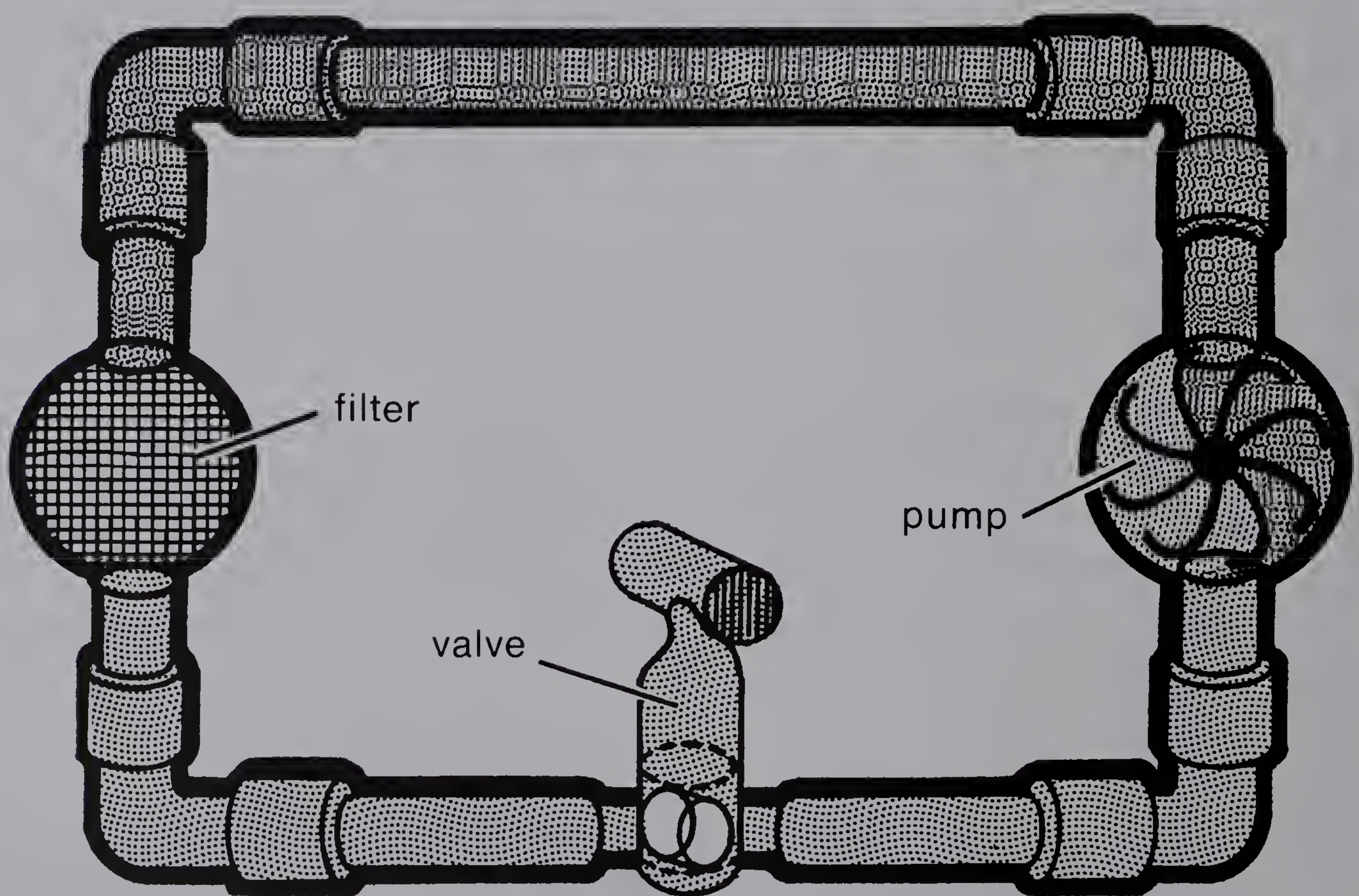


C. Get your circuit again. Add a knife switch and a third wire, as shown. Plug in the power supply Open and close the switch several times. It is perfectly safe to touch the switch as long as you handle it only by the insulated handle and base.

2-13. The light goes on when the switch is closed.

• 2–13. Describe what happens when you open and close the knife switch.

When you open the switch, you break the path through which electrons flow. The air gap is good insulation. No electrons can go through this point. It is like closing a valve in the water circuit. The flow of water is blocked. Even though the pump keeps working and there is plenty of pressure, the water flow has stopped. If the valve blocks the flow of water there is no flow of water anywhere in the system.



2-14. To open or close the circuit.

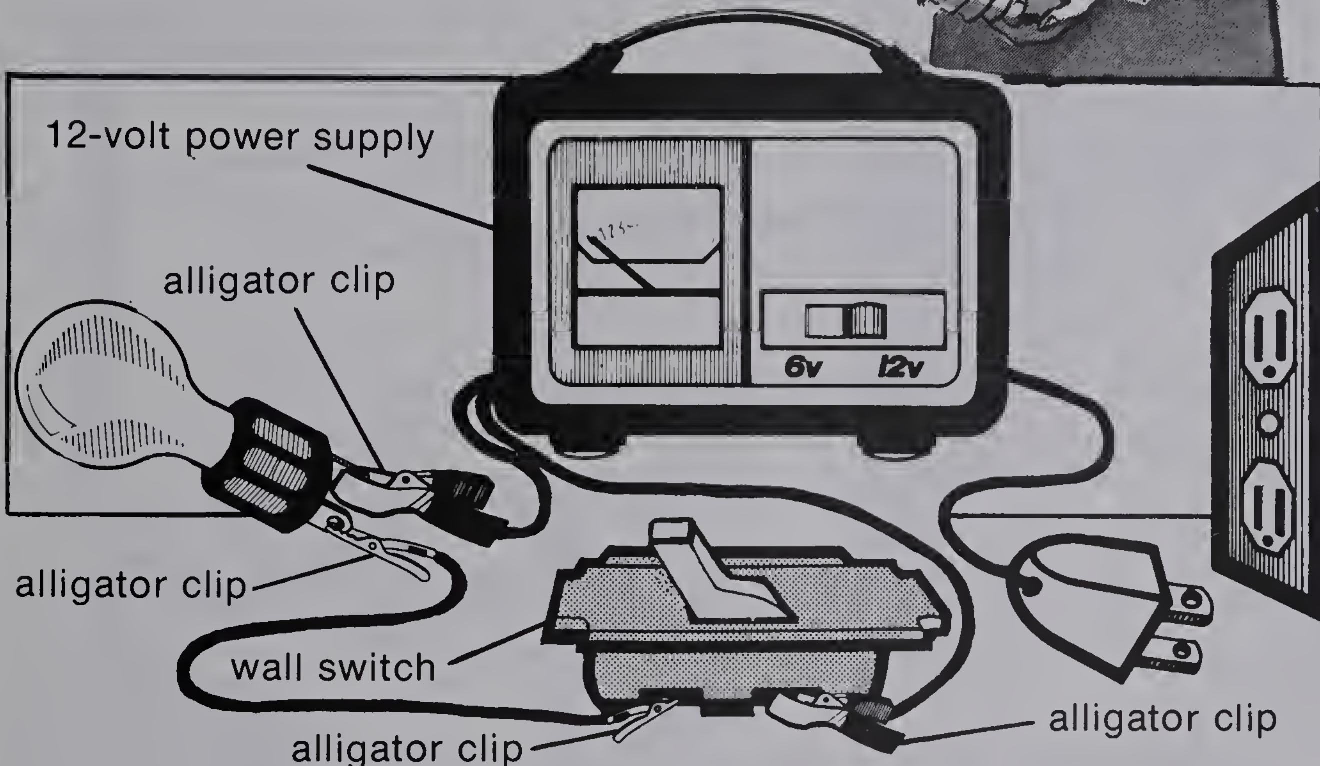
• 2–14. What is the function of a switch?

2-15. No.

• 2–15. If there is not a complete path made of conductors, can there be an electric current?

D. Now get the regular wall switch. Turn it on and off a few times. Study how it works.

E. Connect the wall switch in the circuit in place of the knife switch. You may need a screwdriver. Then plug in the power supply and observe what happens when you turn the switch on and off. Then unplug the power supply.



• 2–16. Describe what happens when you turn the switch on and off.

2-16. The light goes on and off.

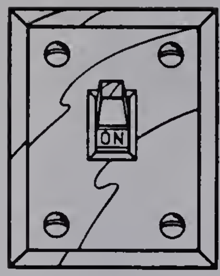
★ **2–17. Match each part of an electric circuit with the corresponding part of a water system. You may want to go back and look at Figure 2–2 and 2–3.**

2-17. a-8, b-3, c-6, d-7, e-2, f-1, g-4, h-5

Electric Circuit	**Water Circuit**
a. electrons	**1. pipe**
b. switch	**2. rate of flow of water**
c. insulation	**3. valve**
d. power supply	**4. pressure**
e. electric current	**5. filter**
f. conductor	**6. walls of pipe**
g. voltage	**7. pump**
h. lamp	**8. water**

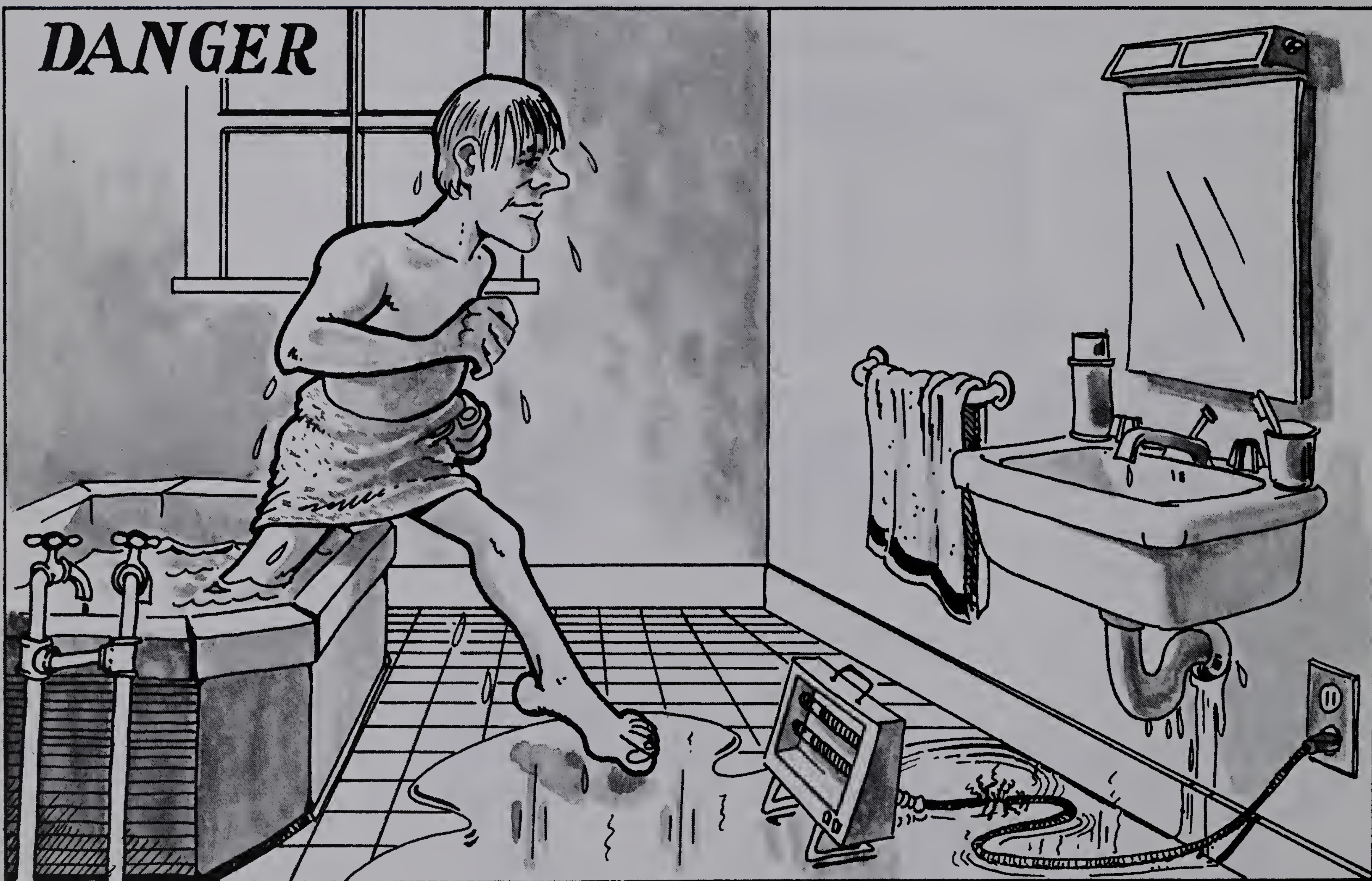
ACTIVITY EMPHASIS: Electric shock can be avoided by making sure your body does not complete a circuit or conduct electricity to a ground.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.
See also Advance Preparation, p. TM 5.



Activity 3
Playing It Safe

Have you ever touched an electrical appliance and got a shock? Even if you haven't, you have probably come very close to it. Maybe without knowing it! An electric shock can be very unpleasant. Sometimes, it is fatal. But if you understand what causes an electric shock, you can learn how to avoid getting one.



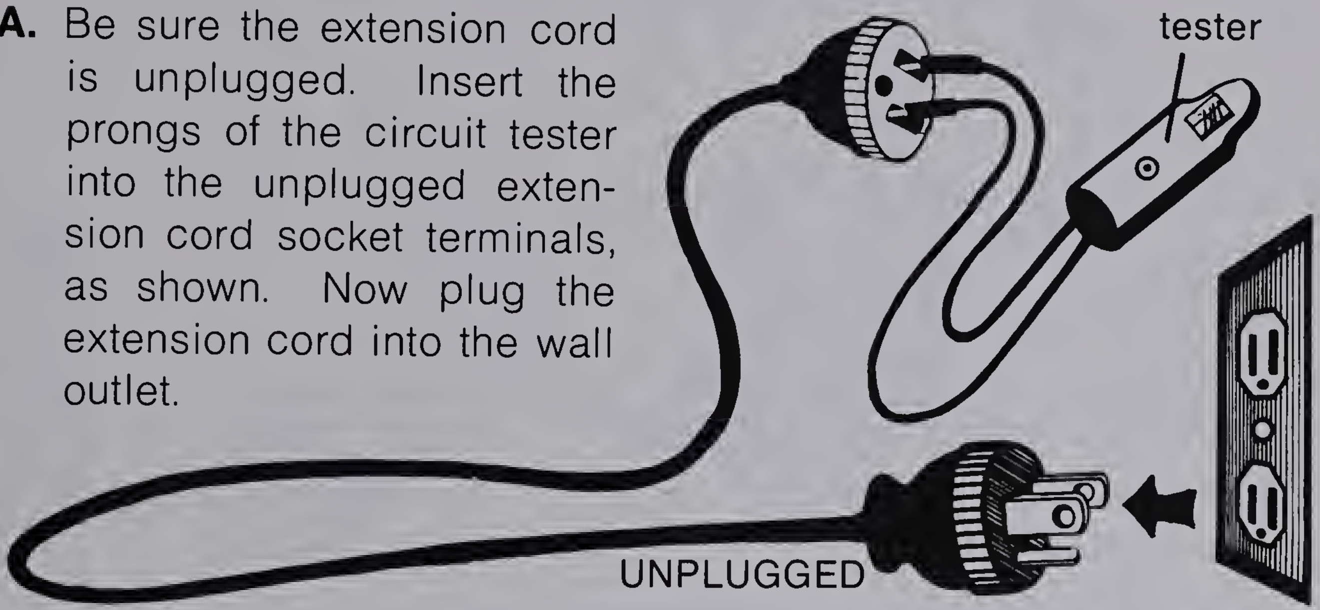
You get a shock only when electricity passes through your body. To find out how that can happen, you can do some investigations. You will not get a shock if you follow directions. You will need the following materials:

3-wire extension cord
circuit tester
insulated #18 wire, 3 m

CAUTION **Don't touch the metal prongs of the tester when using it. Touch only the insulated portion.**

Be sure your hands are dry when working with electricity.

A. Be sure the extension cord is unplugged. Insert the prongs of the circuit tester into the unplugged extension cord socket terminals, as shown. Now plug the extension cord into the wall outlet.



The circuit tester has a bulb that will light when there is current in it. You can use it to find out what connections must be made to a plug to get electrons to flow.

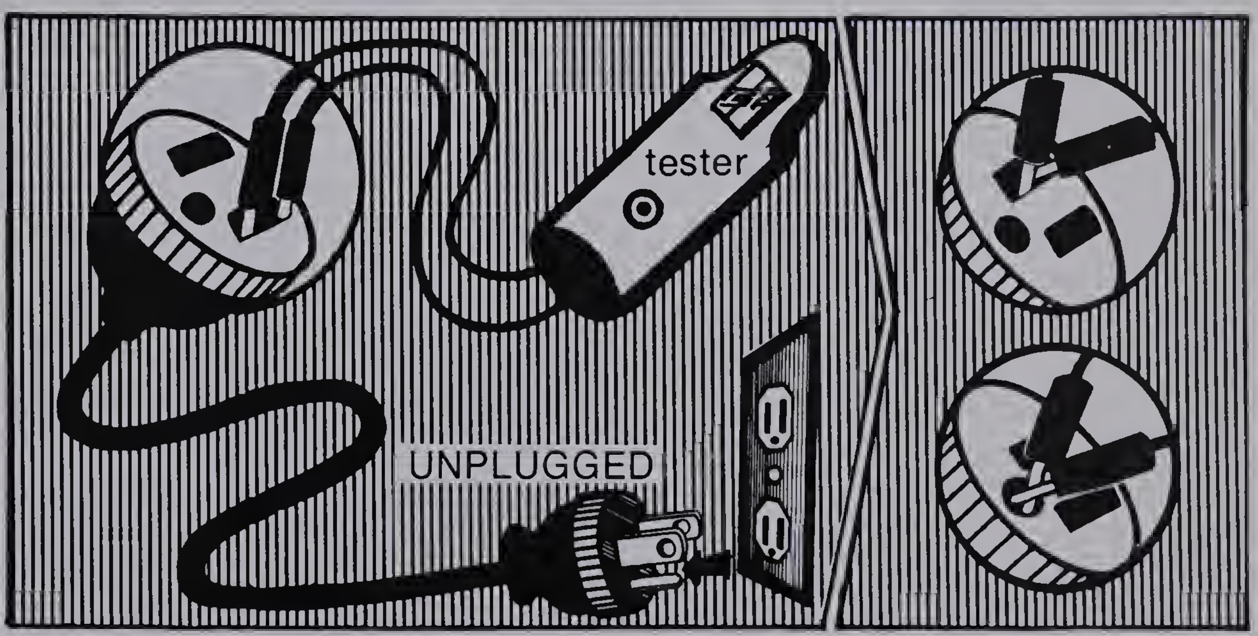
- 3–1. Where should your other hand be while you plug in the cord? If you don't know, look at Activity 2.

3-1. Behind your back.

- 3–2. When the extension cord is plugged in, are electrons flowing through the tester? Is there any current in the tester?

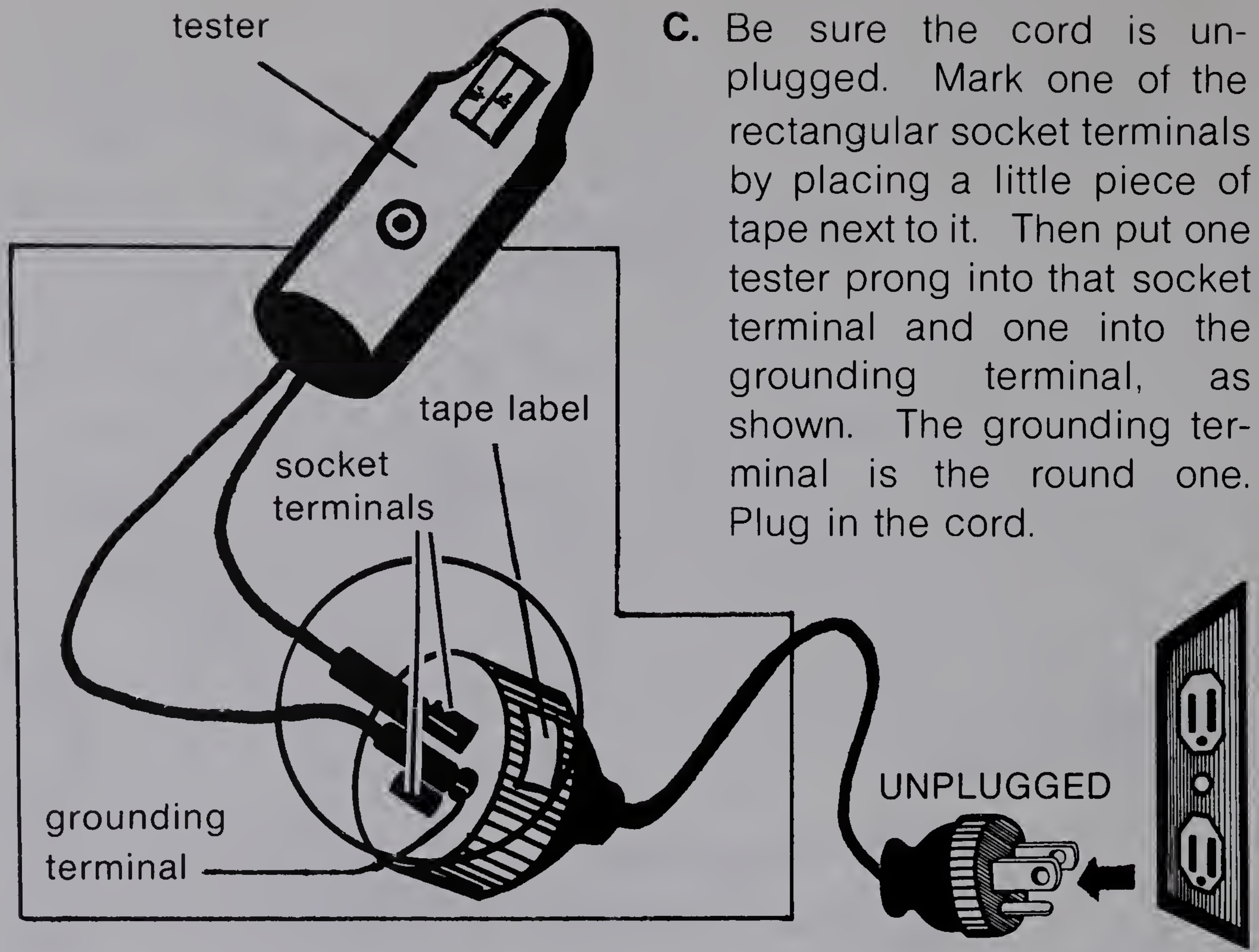
3-2. Yes. Yes.

B. Unplug the extension cord. Insert both prongs of the tester into one socket terminal of the extension cord as shown. Plug in the extension cord. Does the tester light up? Insert both prongs of the tester in each of the other two terminals of the extension cord. Be sure to unplug the cord after each terminal is checked.



- 3–3. Is it possible to get any current by connecting both prongs to the same socket terminal? Explain your answer.

3-3. No. A complete circuit has not been made.

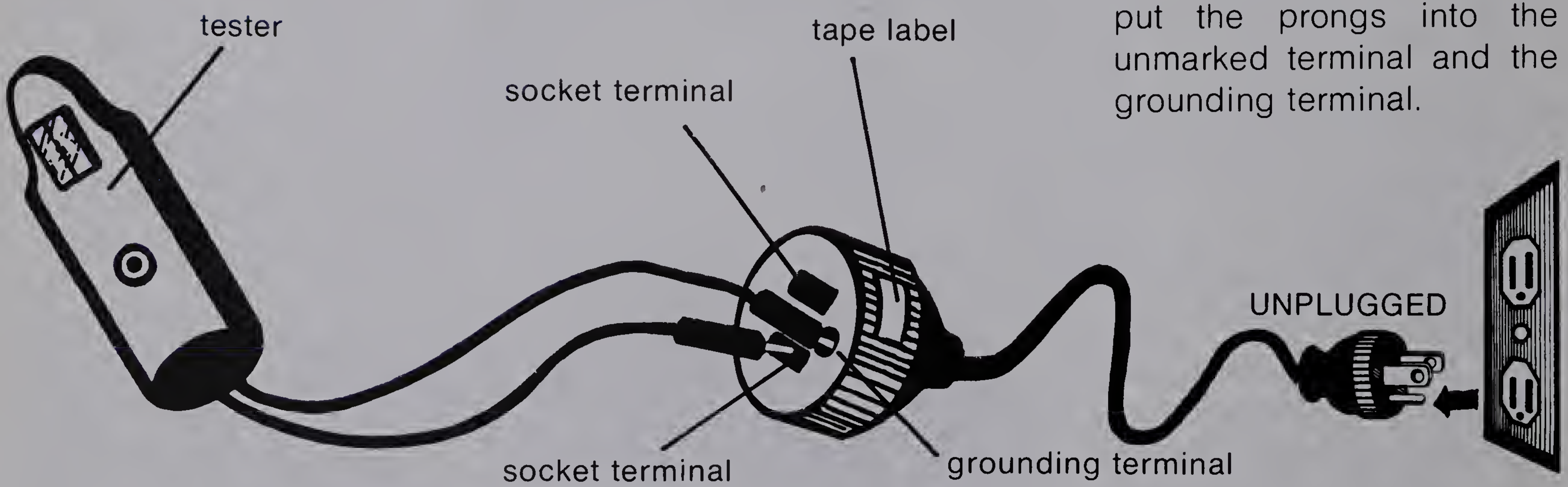


C. Be sure the cord is unplugged. Mark one of the rectangular socket terminals by placing a little piece of tape next to it. Then put one tester prong into that socket terminal and one into the grounding terminal, as shown. The grounding terminal is the round one. Plug in the cord.

3-4. Answers will vary. No, if it doesn't light; yes, if it does light.

• 3–4. Is there any current?

D. Repeat Step C, but this time put the prongs into the unmarked terminal and the grounding terminal.



3-5. Answers will be opposite to Question 3-4.

• 3–5. Is there any current this time?

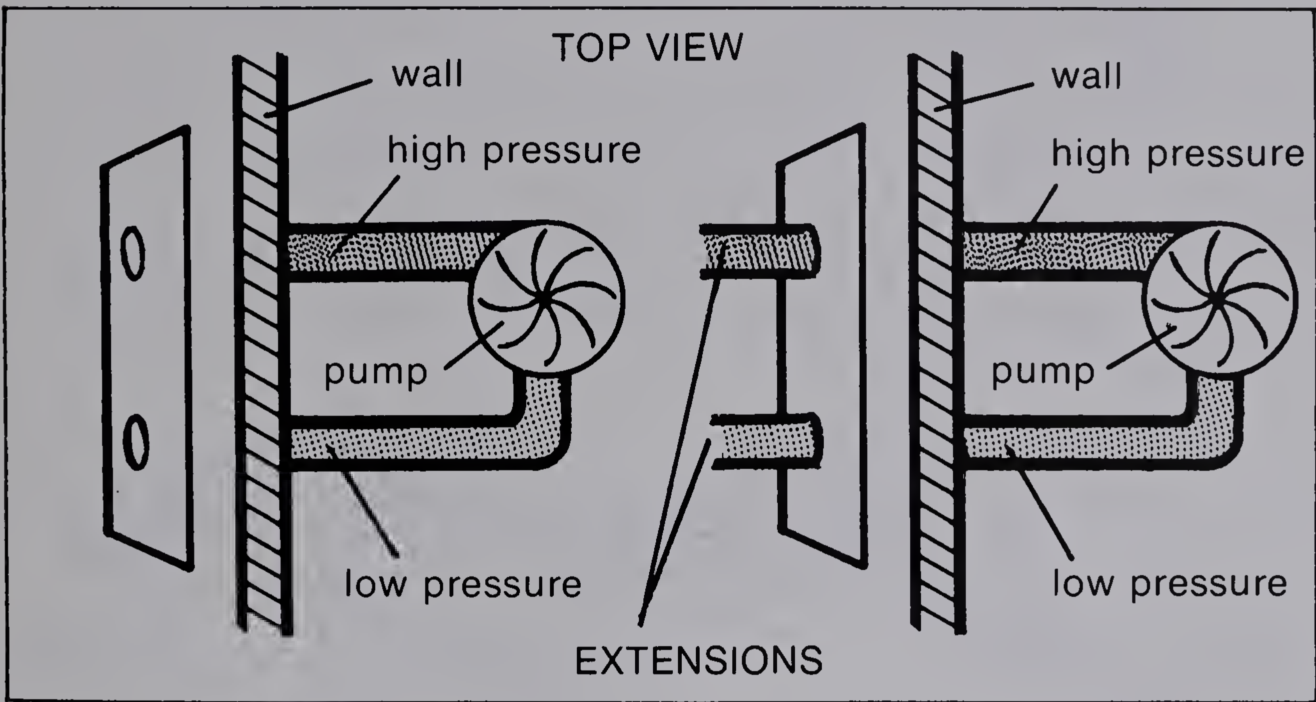
You should get different answers to Questions 3–4 and 3–5. If you did not, try again.

Only one of the two rectangular socket terminals can supply current to the tester. That one is called the *hot* terminal. The other is called the *neutral* terminal.

3-6. Answers will vary.

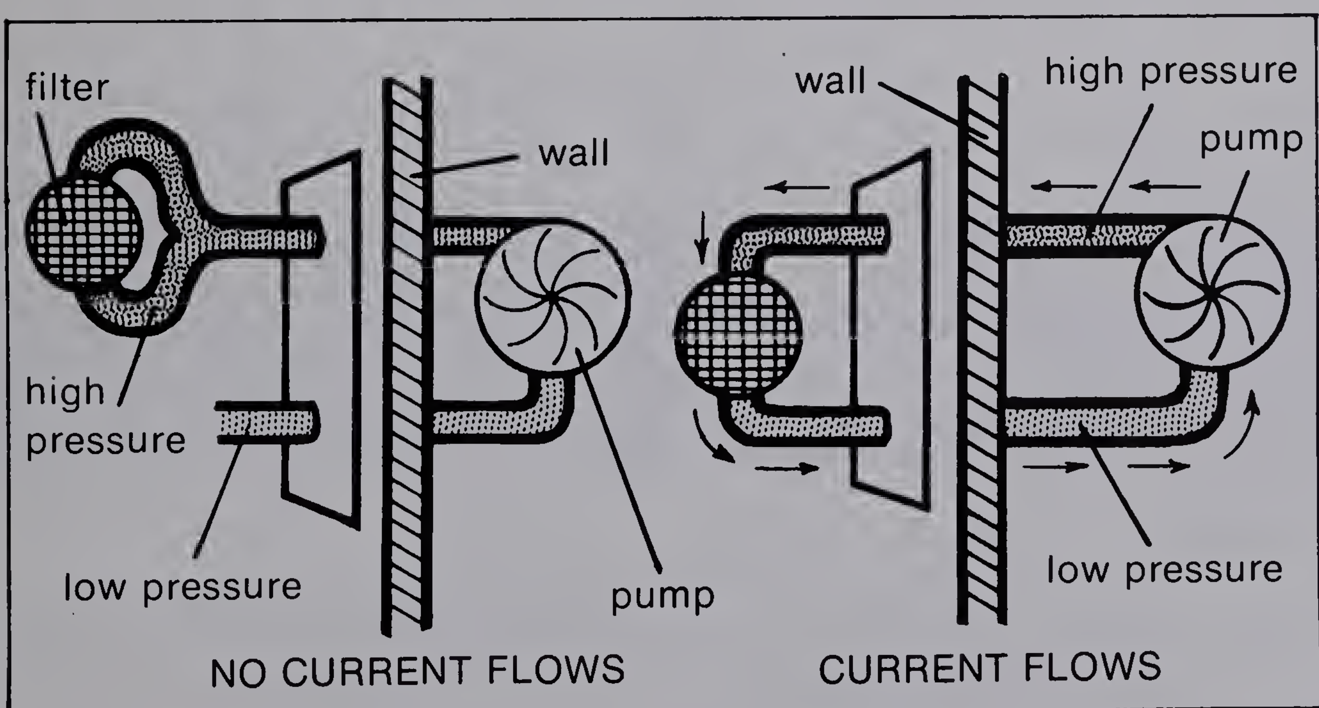
• 3–6. In your setup, was the hot terminal the one that was marked by a piece of tape?

Look at those relationships in terms of the water circuit. The wall outlet is like a water pipe with closed ends connected to a pump. Your local electric company is your power supply, the "pump." When you connect the extension cord, it is the same as making the pipes longer. For now, ignore the third wire in the cord—the grounding wire.



You can connect both prongs of the tester to the same terminal. Or you can connect both ends of the filter to the same pipe. But that will not make it possible for electrons, or water, to flow. It doesn't matter how high the voltage is, or how high the pressure is.

To get current or water to flow, you have to complete the "circuit." When the filter is properly used, it forms a complete path between high and low pressure points. When the tester is properly used, it forms a complete conducting path between the high and low voltage terminals.



In house wiring, as in any electric circuit, it takes two wires to carry the electricity in and out. One is the high-voltage, or hot wire. All hot wires and terminals are carefully insulated. They can be reached only by taking something apart.

The remaining wire is called the *neutral*, or *ground-return* wire. This wire does carry current whenever there is current in the hot wire. This is what makes the ground-return wire different from the ground wire. Any conductor that is connected to the earth by a conducting path has essentially the same voltage as the earth—zero voltage. Such conductors are said to be *grounded*. Thus, both the ground and the ground-return wire are grounded. In addition, your house is full of grounded objects.

Unless something is wrong with the wiring or with the appliance, it should not be possible ever to touch a hot wire by accident.

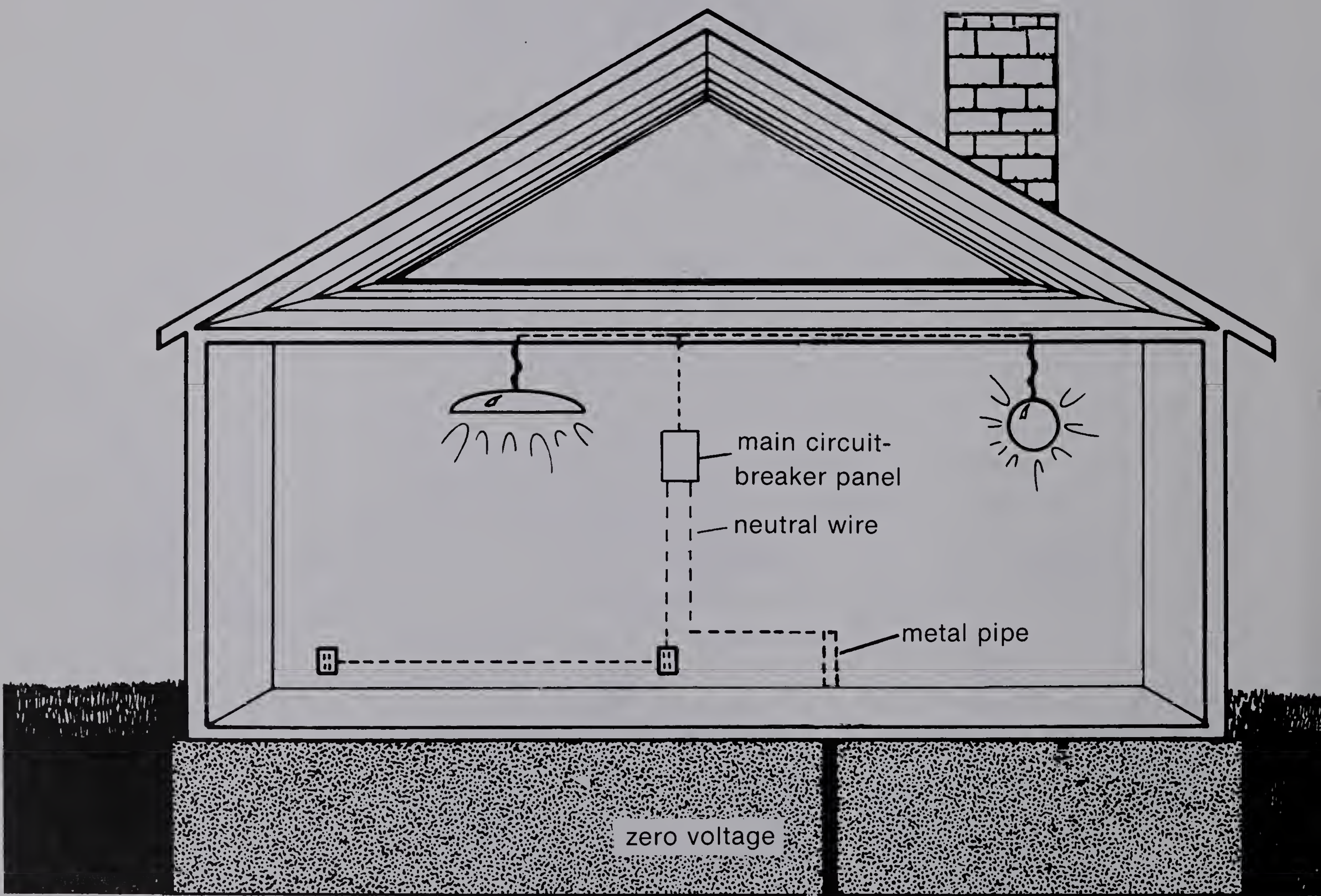


Figure 3–1

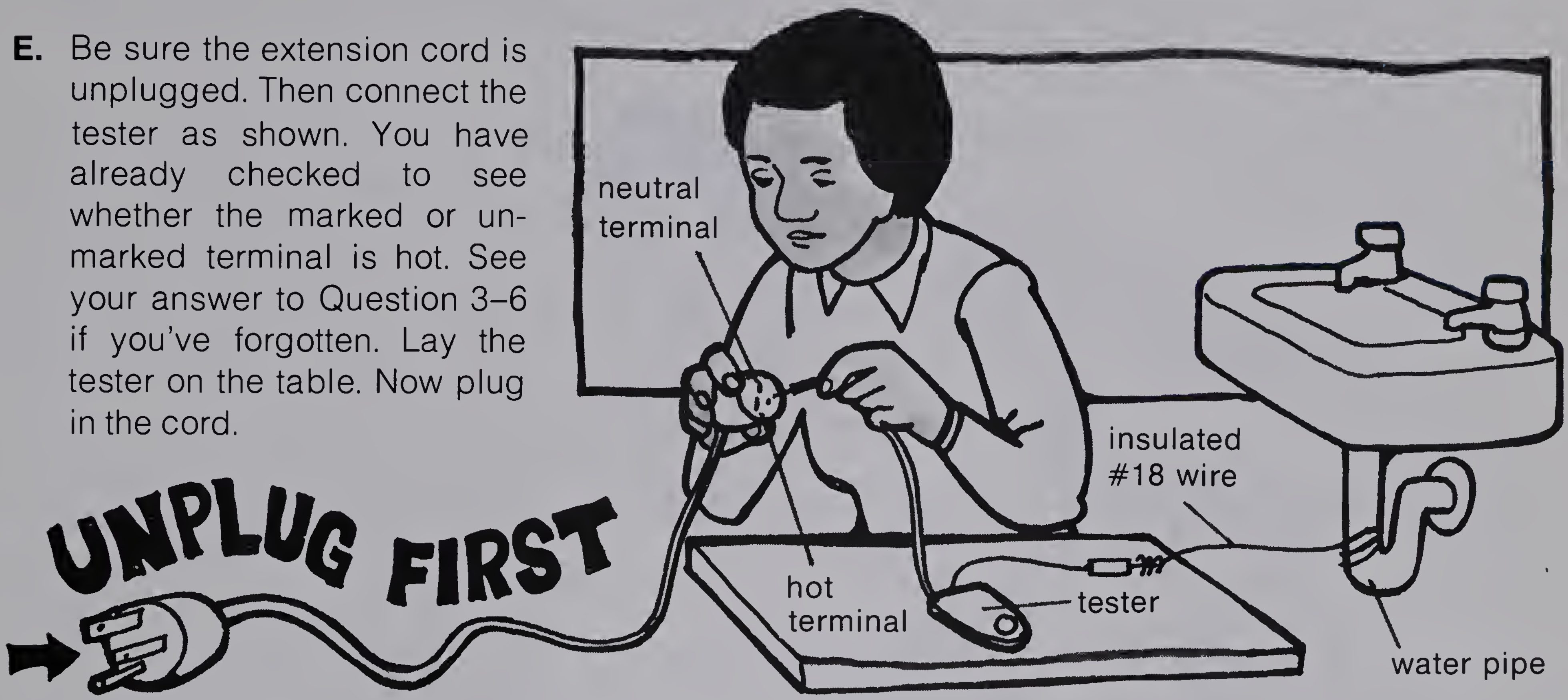
3-7. By connecting them to a metal pipe that goes into the ground.

• 3–7. Look at Figure 3–1. Tell how the neutral wires in circuits are usually grounded.

You can see the effects of this grounding. You want to see whether electrons will flow through the tester when it connects the hot wire to a grounded object, or a ground. A water pipe makes a good ground.

Note: Using a sink drain may not be a reliable practice in new homes with plastic (PVC) connecting pipes.

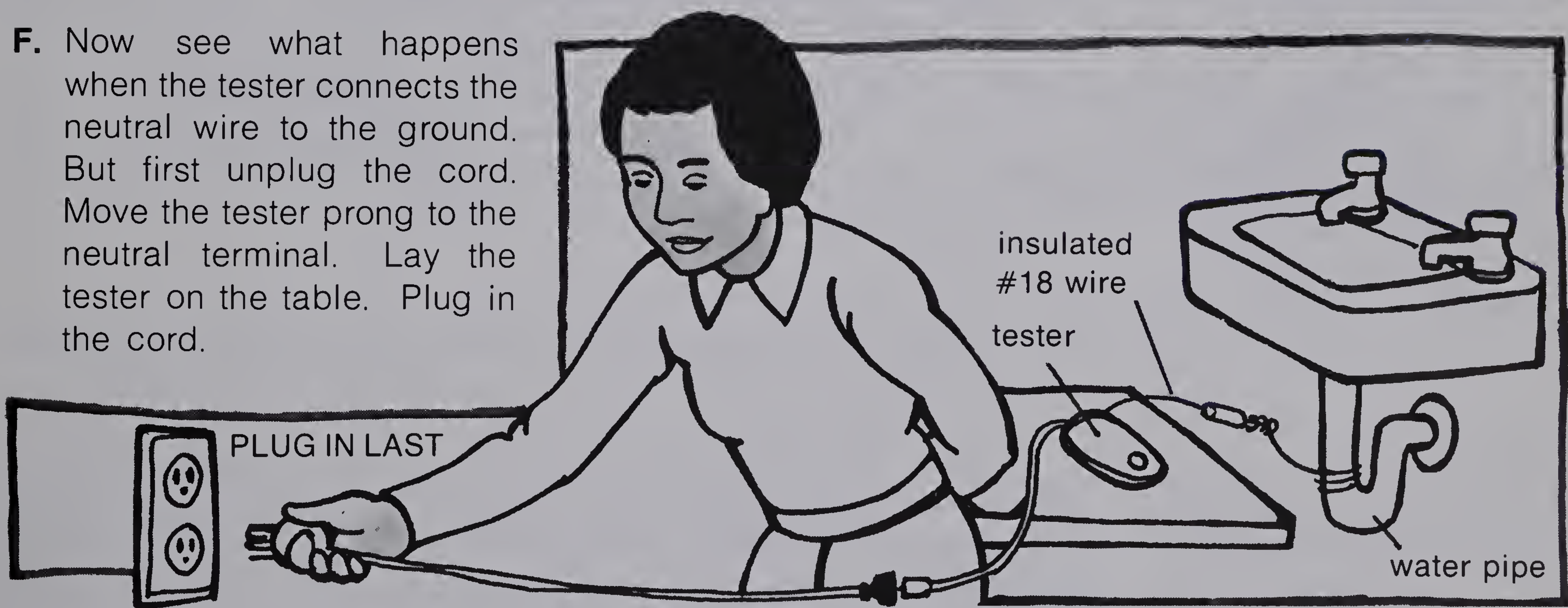
E. Be sure the extension cord is unplugged. Then connect the tester as shown. You have already checked to see whether the marked or unmarked terminal is hot. See your answer to Question 3–6 if you've forgotten. Lay the tester on the table. Now plug in the cord.



★ **3–8. How can you tell if there is a current passing through the tester?**

3-8. The tester light goes on.

F. Now see what happens when the tester connects the neutral wire to the ground. But first unplug the cord. Move the tester prong to the neutral terminal. Lay the tester on the table. Plug in the cord.



• 3–9. Is there a current flowing through now?

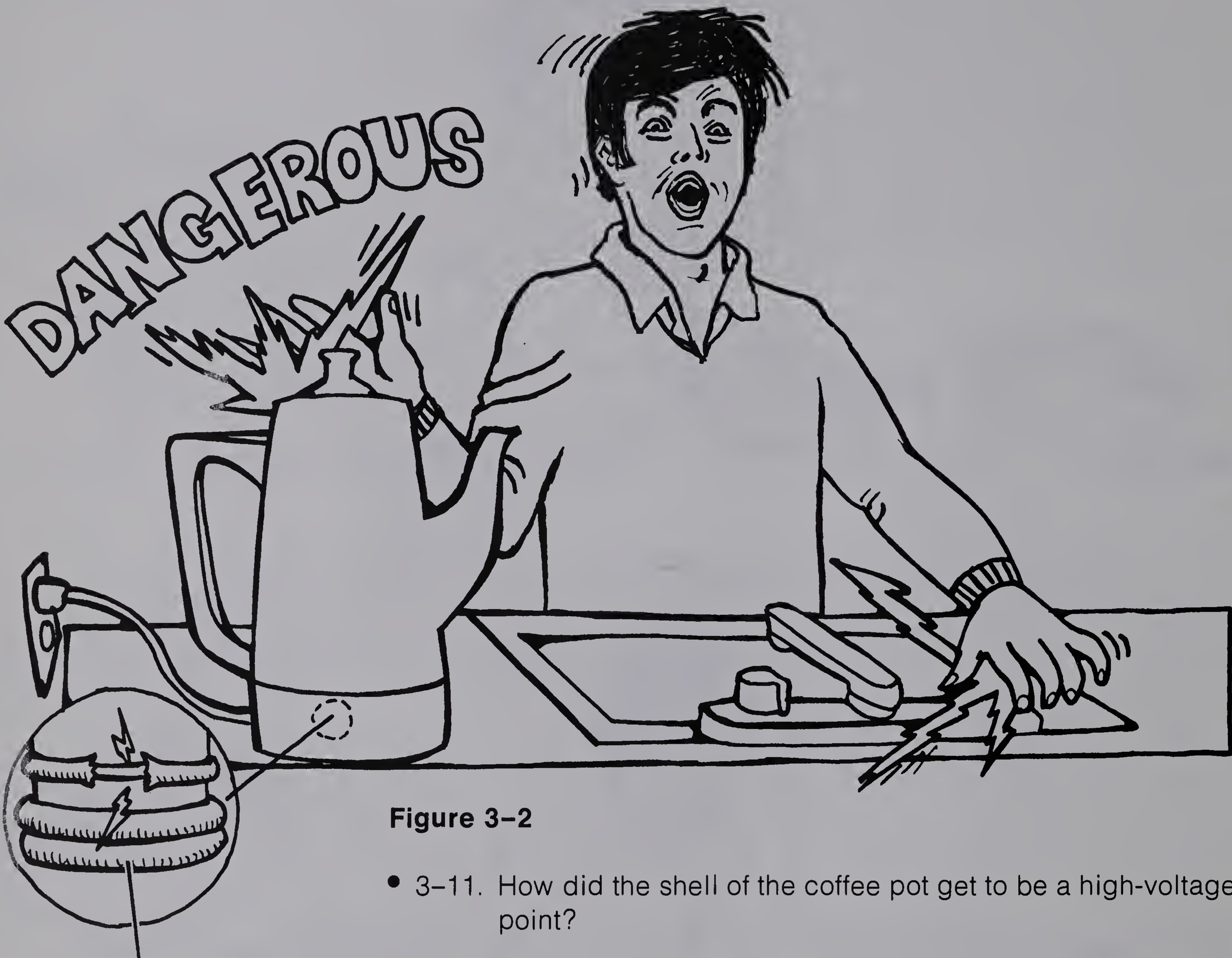
3-9. No.

• 3–10. In order for electrons to flow in a household circuit, there must be a conducting path from the hot wire to
a. another hot wire.
b. a ground.

3-10. (b) A ground.

When someone gets a shock, it is usually because the person has one hand or foot on a "hot" source and the other hand or foot grounded. If your appliances are in good shape and you are not fooling around with the wiring, there is no way you can get a shock.

But people do get electric shocks. Look at Figure 3–2.



heating element

Figure 3–2

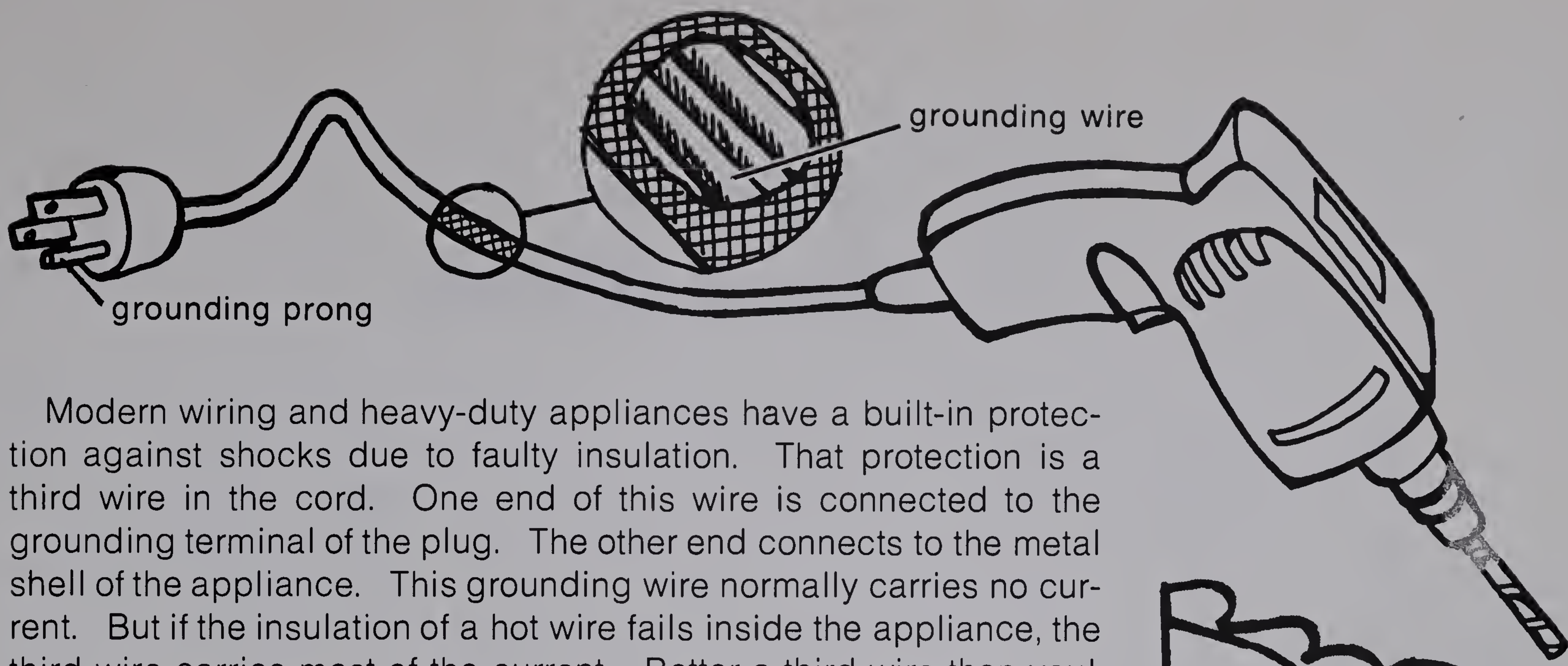
• 3–11. How did the shell of the coffee pot get to be a high-voltage point?

3-11. A wire to the heating element is conducting to the shell.

A person will not get a shock unless a circuit is completed through the person's body. This may happen if a foot or some other part of the body is grounded. Bathrooms are especially dangerous because tap water can be an excellent conductor. If you are standing on a wet floor, and the water is touching a pipe, your feet are grounded. Of course, it's not necessary to have wet feet. You could get the same results by touching the water faucet or any other good ground.

★ **3–12. When your feet are wet, how can you avoid electric shock?**

3-12. Wet feet are excellent conductors to ground.



Modern wiring and heavy-duty appliances have a built-in protection against shocks due to faulty insulation. That protection is a third wire in the cord. One end of this wire is connected to the grounding terminal of the plug. The other end connects to the metal shell of the appliance. This grounding wire normally carries no current. But if the insulation of a hot wire fails inside the appliance, the third wire carries most of the current. Better a third wire than you!

The person shown in Figure 3–3 is making a bad mistake. The toaster is plugged in and there is a piece of toast stuck inside. A fork is being used to get the toast out. But that heating element is at a high voltage.

Figure 3–3

- 3–13. What happens if the fork touches the heating element and the person's other hand is grounded?

There is less danger here if the outer shell of the toaster is not grounded. Then there will be no shock even if the fork touches the hot wire inside and the other hand touches the shell. Because people do stick forks into toasters, these shells are intentionally not grounded. Regardless, always unplug toasters or any other appliance before working on them.

- 3–14. Before you use a fork to get toast out, what should you do?

Inside the walls of many buildings, circuit connections are encased in metal. Every switch, lighting fixture, and receptacle is in a metal box. In some cases, wires run through metal pipes that connect one box to another. All the enclosures are connected together and grounded.

This metal enclosure has two important functions. First, if any wires get frayed, current is immediately grounded. And second, if lightning strikes, it is carried to ground through the metal casing of the electrical system. Without the box, either a frayed wire or a bolt of lightning could more easily start a fire.

- 3–15. Describe the design features of a household circuit that reduce the danger of damage by lightning.

★ **3–16. From which two dangers can grounding protect you?**

3-13. Since there could be a current through the body from one hand to the other, the person could get a shock.

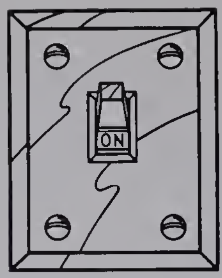
3-14. Unplug the toaster.

3-15. Electrical fittings are encased in metal, and the casings are grounded.

3-16. Shock and fire.

ACTIVITY EMPHASIS: Home wiring circuits and protection devices are arranged to provide convenience and safety.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.



Activity 4
Home Wiring

The wiring in your home is probably something you take for granted. But if you count the electrically operated gadgets, you may be surprised at the number of them. The wiring in your home must be planned to provide the electric current all those gadgets use.

To get an idea of the relationship among the parts in a household circuit, look at Figure 4–1. Think of it as either a water or an electrical system. Then answer the questions about it.

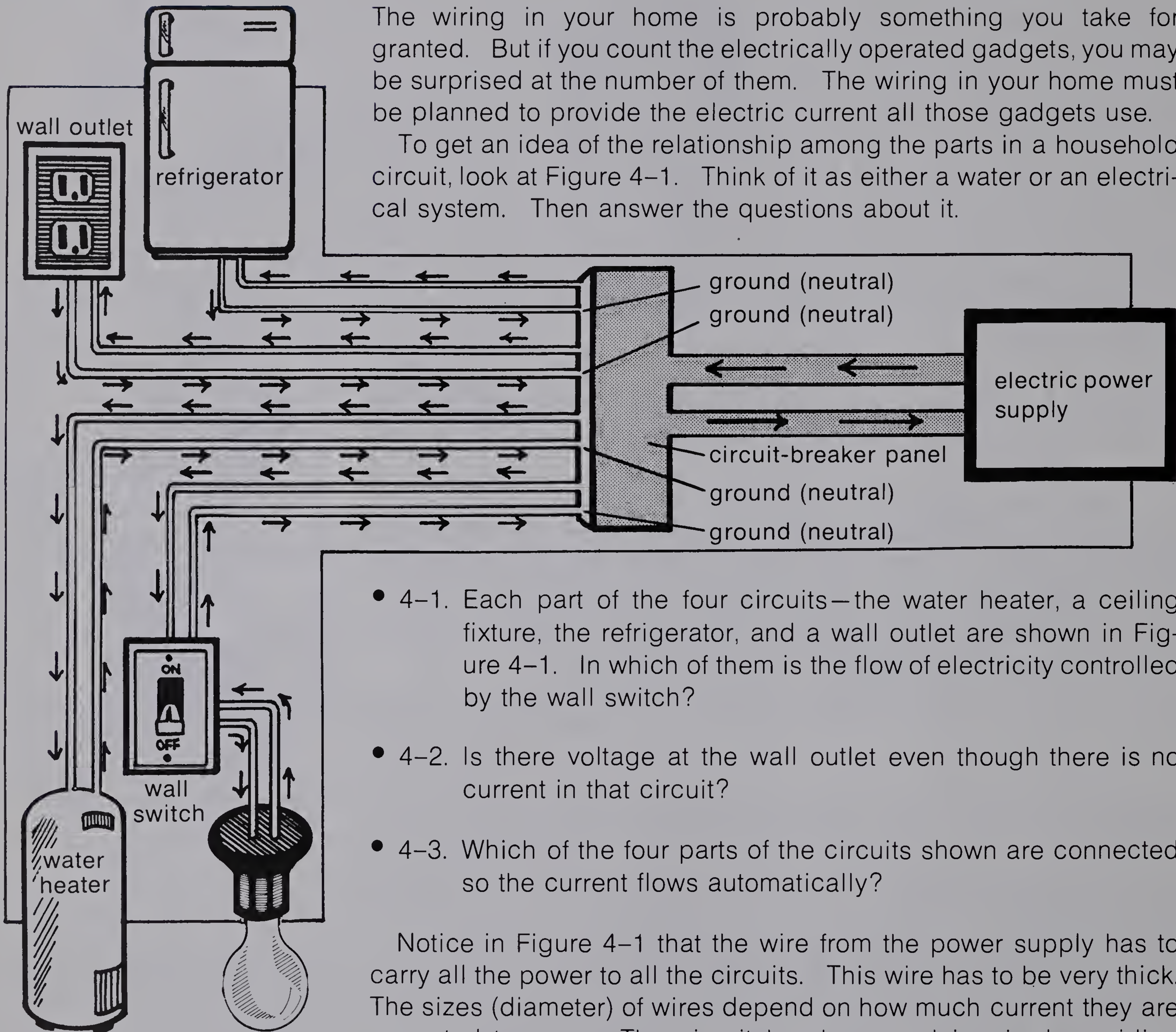


Figure 4–1

- 4–1. Each part of the four circuits—the water heater, a ceiling fixture, the refrigerator, and a wall outlet are shown in Figure 4–1. In which of them is the flow of electricity controlled by the wall switch?

- 4–2. Is there voltage at the wall outlet even though there is no current in that circuit?

- 4–3. Which of the four parts of the circuits shown are connected so the current flows automatically?

Notice in Figure 4–1 that the wire from the power supply has to carry all the power to all the circuits. This wire has to be very thick. The sizes (diameter) of wires depend on how much current they are expected to carry. The circuit breaker panel is wired providing power to all circuit branches. Each branch has its own fuse or circuit breaker. These fuses or circuit breakers protect the circuit from getting too much current.

★ **4–4. What two things can protect single appliance circuits from too much current?**

4-1. Ceiling fixture.

4-2. Yes.

4-3. Refrigerator and water heater.

4-4. Circuit breaker and fuse.

Now look at Figure 4–2. This shows the way a house is wired. A water heater and a range take a lot of current. They must be supplied with thick wires. Thinner wires are used for circuits that supply lights or other small appliances. Look at Figure 4–2 carefully, then answer the questions.

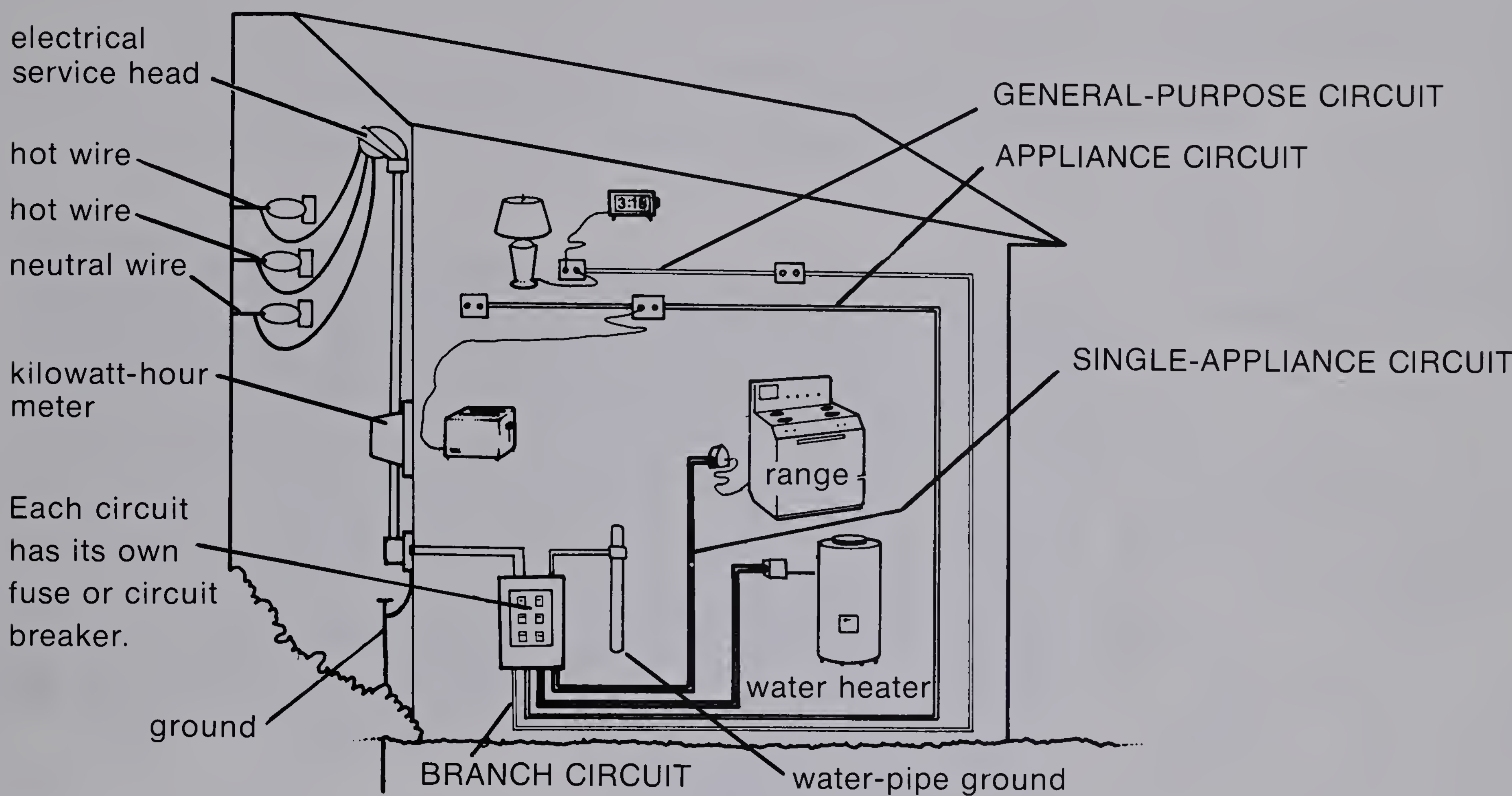


Figure 4–2

- 4–5. What three things does electricity have to go through before it gets into the branch circuits in the home?

4-5. Service head, electric meter, panel.

★ **4–6. According to Figure 4–2, what are the three kinds of branch circuits commonly used in a home?**

4-6. Single appliance, appliance, and general purpose.

The branch circuits are not all alike. Notice that three wires carry electricity into the house—two wires are "hot" and one is a neutral, or ground. The wires that bring electricity in can be connected to make branches. These branches can carry either 110 volts or 220 volts. Most of the circuits carry 110 volts.

But if a special appliance, such as a range, a large air conditioner, or a water heater, uses a lot of power, it is supplied by a single appliance circuit. This circuit is usually at 220 volts.

The 110-volt circuits are not all alike either. The line to a kitchen, where a lot of appliances are used, is made of thicker wire than most of the other branches. Most branch circuits—general purpose circuits—can carry only 15 amperes of current safely. But the kitchen line, an appliance circuit, can carry 20 amperes.

4-7. a

★ **4–7. In Figure 4–2, which room needs a branch circuit with the largest current capacity?**

a. kitchen
b. bedroom
c. bathroom
d. living room

All wiring should be done according to the *National Electrical Code*. It is a book with more than six hundred pages. Figure 4–3 shows what part of a page from the 1975 edition looks like.

230-79. Rating of Disconnect. The service disconnecting means shall have a rating not less than the load to be carried, determined in accordance with Article 220. In no case shall the rating be lower than specified in (a), (b), (c) or (d) below.

(a) One-Circuit Installation. For installations to supply only limited loads of a single branch circuit, the service disconnecting means shall have a rating of not less than 15 amperes.

(b) Two-Circuit Installations. For installations consisting of not more than two 2-wire branch circuits, the service disconnecting means shall have a rating of not less than 30 amperes.

(c) Single-Family Dwelling. For a single-family dwelling, the service disconnecting means shall have a rating of not less than 100 amperes, 3-wire under either of the following conditions: (1) where the initial computed load is 10 kW or mo (2) where the initial installa

Figure 4–3

4-8. They might not put enough circuits in. They might not put the proper ones to carry the eventual load.

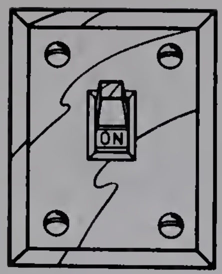
• 4–8. What might happen if the electric circuits were installed any way a building contractor or owner wanted?

Before a house or apartment building can be lived in, it must be inspected to see that the wiring meets the code standards. There must be enough branch circuits. The wires must be thick enough to carry the current that will be used. Everything must be properly insulated and grounded. All the switches, sockets, fixtures, and appliances must carry the safety symbol of the Underwriters Laboratories (UL) or some other recognized testing laboratory.

The *National Electrical Code* is revised often. As people have come to demand more electricity, the code is changed to see that they get it with safety. Older homes may not have been wired for air conditioners, deep freezers, and other modern electric devices.

4-9. Newer houses usually have more branch circuits.

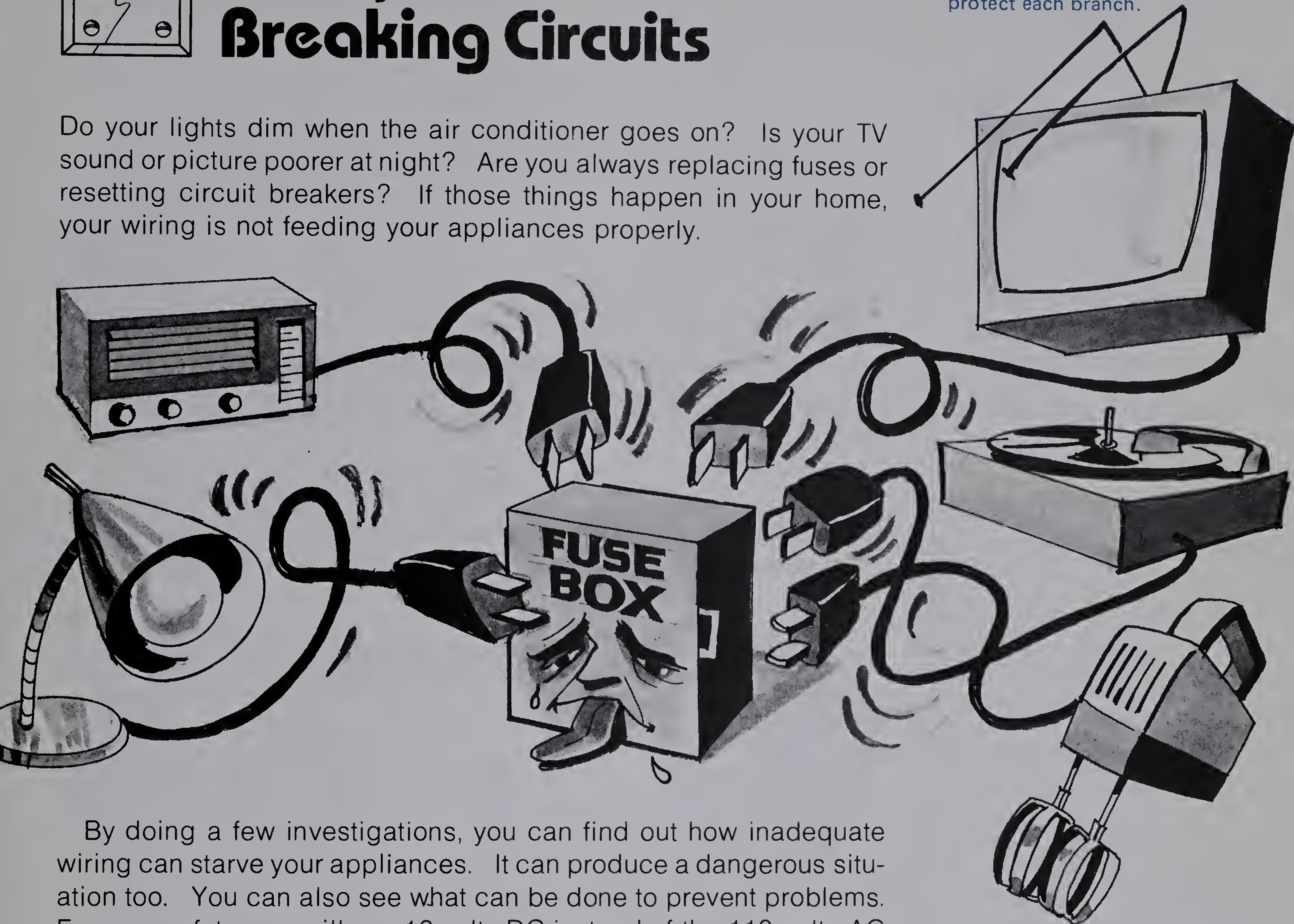
★ **4–9. How would you expect the wiring of new houses to be different from that of older houses?**



Activity 5
Breaking Circuits

ACTIVITY EMPHASIS: The diameter of the wire usually limits the appliance load of a branch circuit. Fuses and circuit breakers protect each branch.

Do your lights dim when the air conditioner goes on? Is your TV sound or picture poorer at night? Are you always replacing fuses or resetting circuit breakers? If those things happen in your home, your wiring is not feeding your appliances properly.



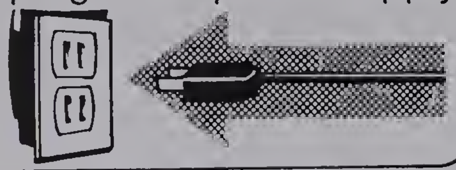
By doing a few investigations, you can find out how inadequate wiring can starve your appliances. It can produce a dangerous situation too. You can also see what can be done to prevent problems. For your safety, you will use 12 volts DC instead of the 110 volts AC from the wall outlet. You will need the following items:

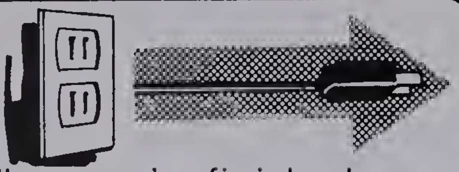
power supply, 12-volt
4 bulb sockets
2 bulbs, 25-watt, 12-volt
2 bulbs, 50-watt, 12-volt
3-outlet receptacle with lead wires attached
screwdriver
thermometer, −10° to 110°C
circuit breaker (5 amperes)
20 cm #22 copper wire (thin)
20 cm #32 copper wire (thinner)
20 cm #40 copper wire (thinnest)
20 cm insulated wire

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.
See also Advance Preparation, p. TM 5.

Note: One 20-cm #40 copper wire will be needed for each lab group doing this activity. This wire is expendable.

After everything is plugged in, plug in the power supply.





When you're finished, unplug the power supply.

CAUTION **Do not touch any 110-volt wires. Never plug the 12-volt bulbs or any other equipment except the power supply into a 110-V receptacle. Always remove the plug while changing the circuit. Plug in the power supply last.**

Be sure your hands are dry when working with electricity.

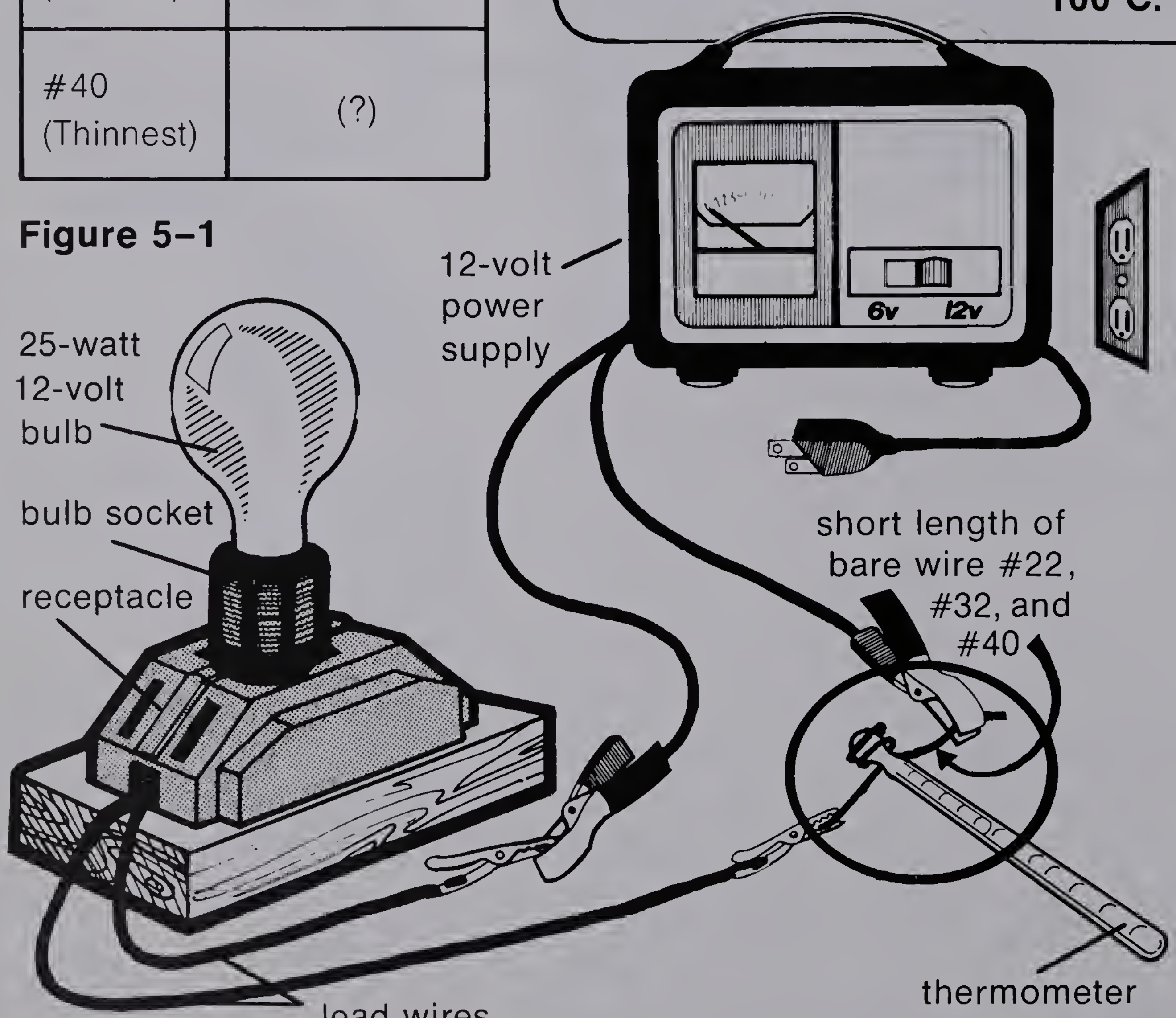
WIRE THICKNESS AND TEMPERATURE

WIRE DIAMETER	WIRE TEMPERATURE
#22 (Thin)	(?)
#32 (Thinner)	(?)
#40 (Thinnest)	(?)

Figure 5–1

First, see how the diameter of the wire affects the operation of the circuit. You need to make a table like the one in Figure 5–1 to record temperature readings in Step A. Remember to remove the plug while changing the circuit. Also, some of the equipment may get hot, so keep it away from anything flammable.

CAUTION **In Step A if the thermometer rises to 100°C, unplug the power supply immediately and record "about 100°C."**



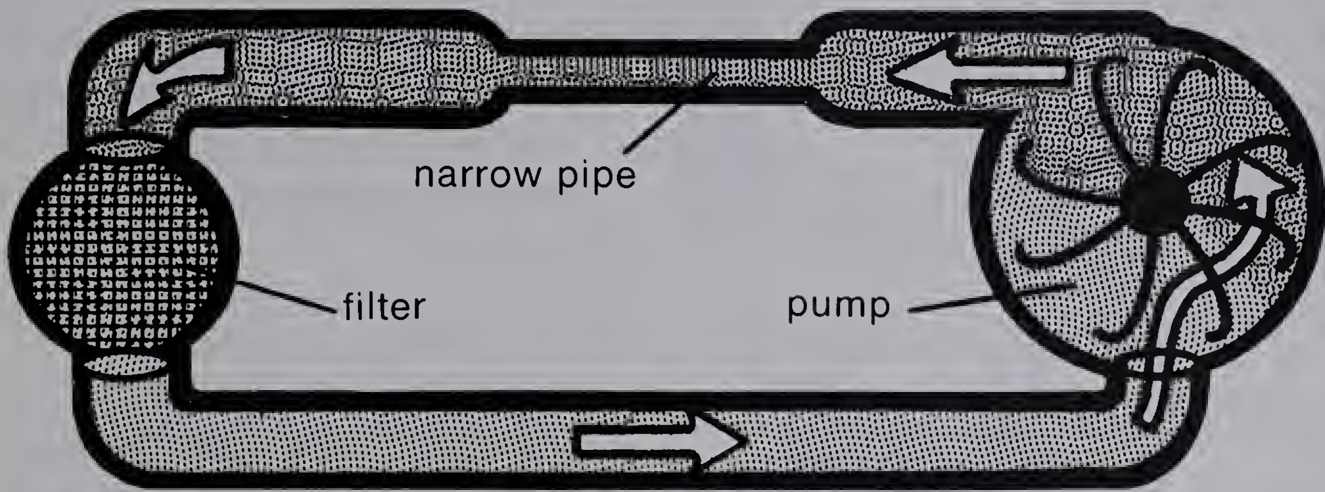
A. Unplug the power supply. Wrap the bulb of the thermometer with the 20-cm length of #22 bare wire. Connect the receptacle and the #22 wire with one 25-watt bulb, as shown. Note that the current has to make part of its trip through your short length of #22 copper wire. Plug in the power supply. Wait until the thermometer stops rising (or reaches 100°C). Record the temperature in your table. Do the same thing with the #32 and the #40 wire. Record these temperatures.

5-1. The thinner wire gets warmer.

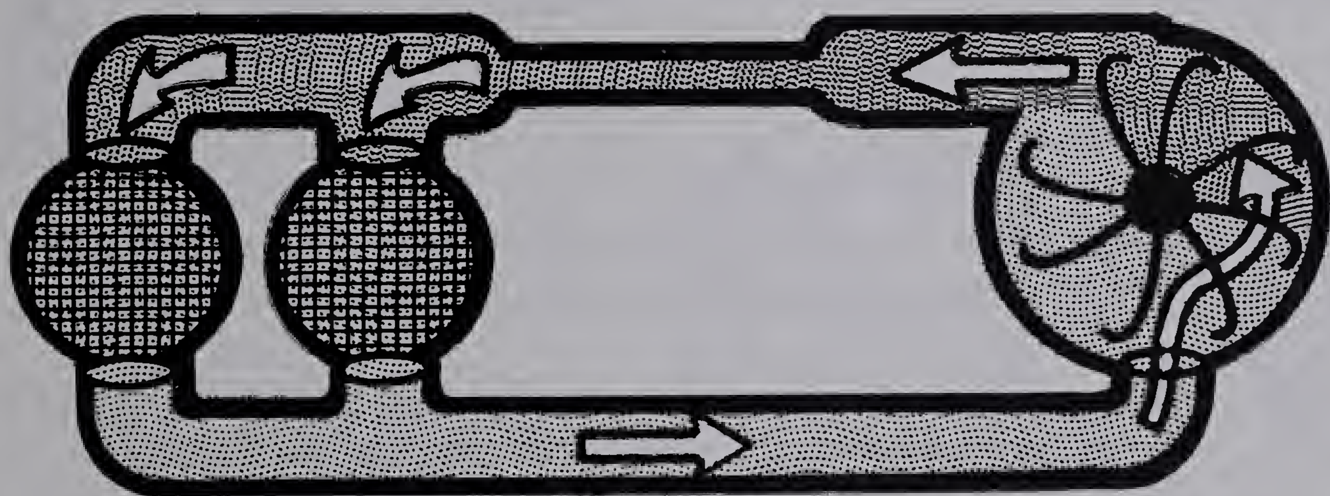
• 5–1. How is the temperature of a wire related to its thickness?

If you could do this experiment with plumbing instead of wires, the explanation might be as follows.

The water has to squeeze its way through a very narrow section of pipe. That uses up a lot of the energy. It reduces the amount of energy that is delivered to the filter. The energy lost in pushing water through a thin pipe is used in heating up the pipe.



Think about what happens if you put a second filter into the circuit. Now the pump has to supply more power. With even more water flowing through the narrow piece of pipe, there is still more useful energy lost there.



- 5–2. What do you predict would happen to the temperature if you set up your thin-wire (#40) circuit with two bulbs in place as shown in Figure 5–2?

5-2. The wire will get hotter than with the single bulb.

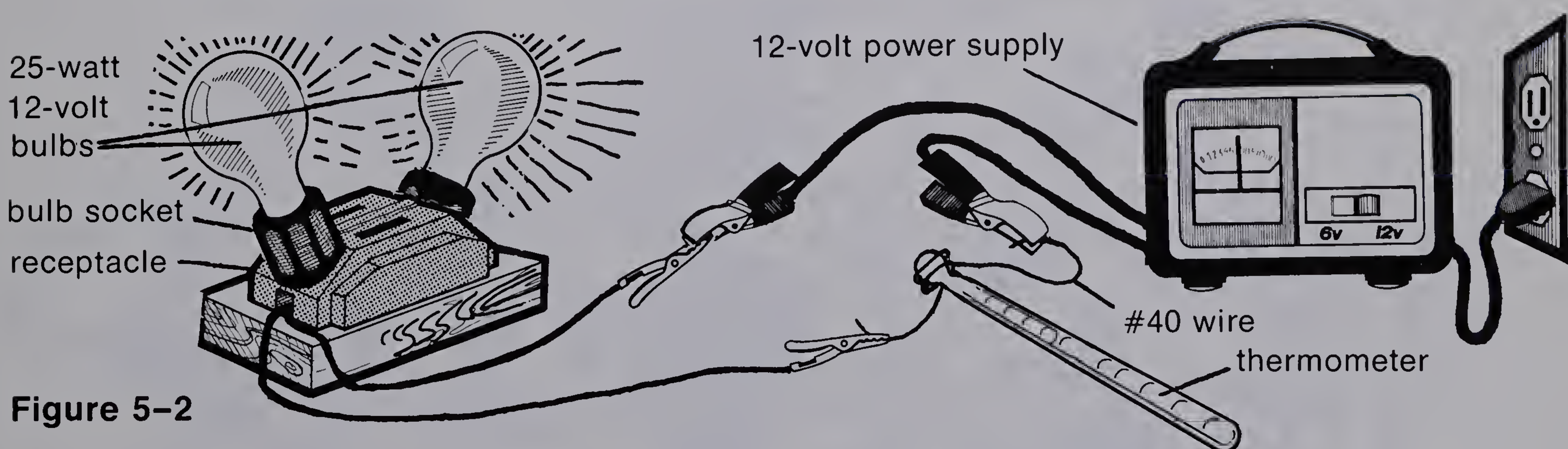
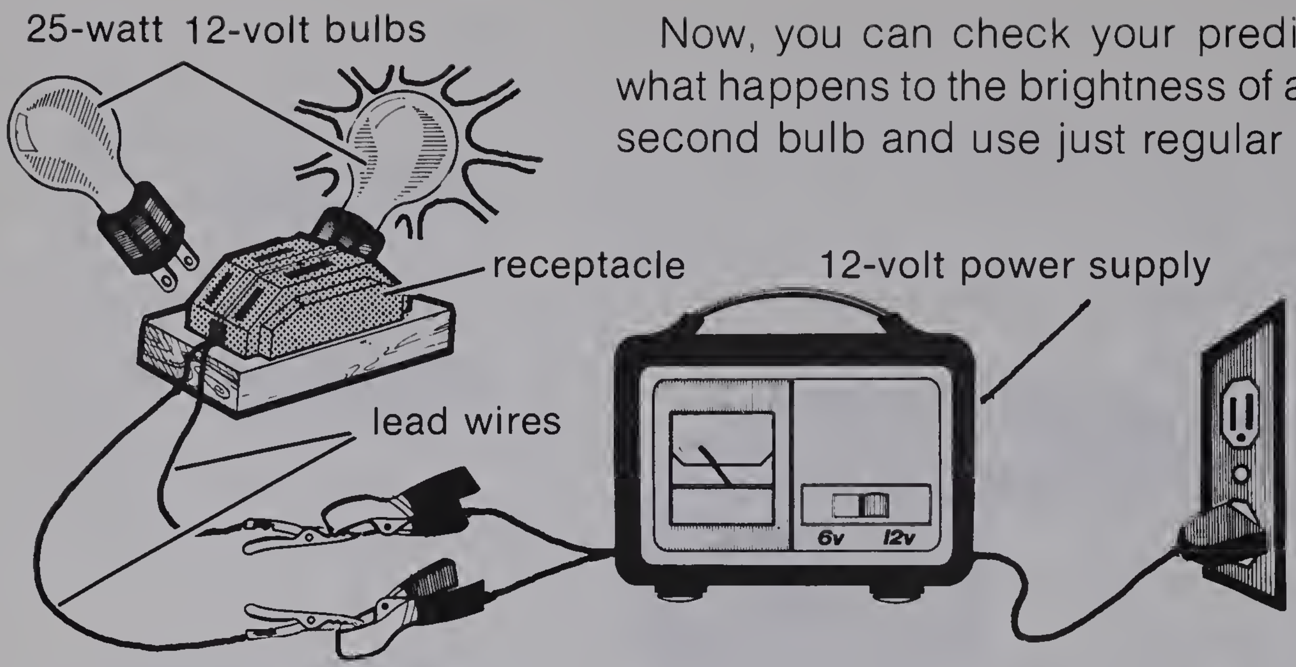


Figure 5–2

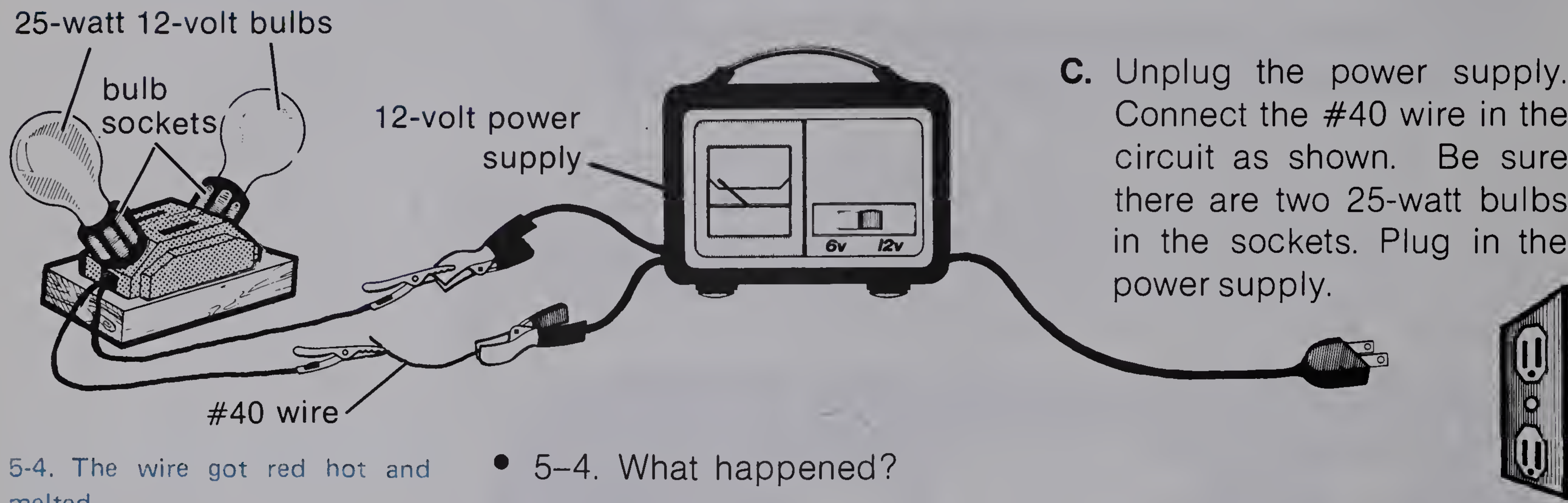
Now, you can check your predictions. First, you need to know what happens to the brightness of a burning bulb when you plug in a second bulb and use just regular wires.



B. Connect the socket with one bulb as shown. Now with the bulb burning, plug in a second 25-watt bulb. It is safe to do this without disconnecting the power supply because glass is a good insulator.

5-3. The first bulb got dimmer.

• 5–3. What happened to the brightness of the first bulb?



C. Unplug the power supply. Connect the #40 wire in the circuit as shown. Be sure there are two 25-watt bulbs in the sockets. Plug in the power supply.

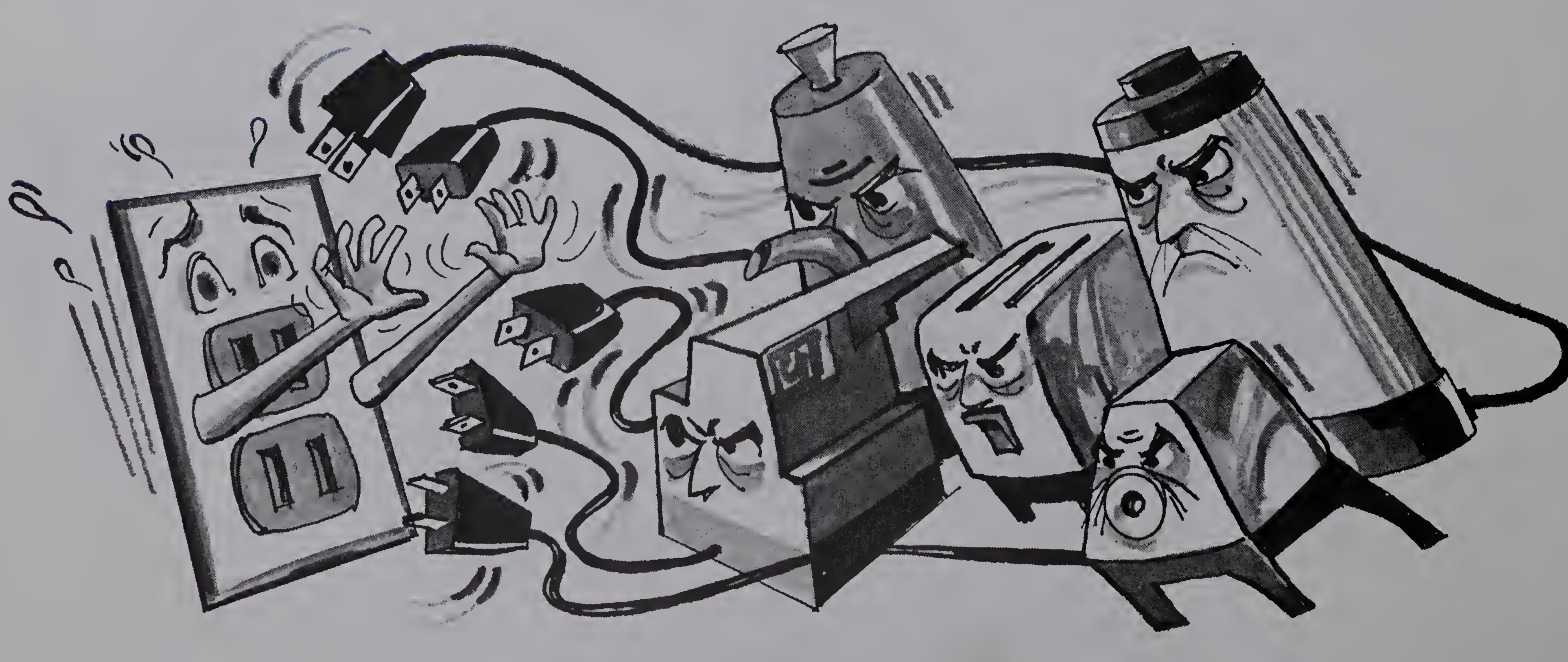
5-4. The wire got red hot and melted.

• 5–4. What happened?

5-5. Thinner wiring cannot carry a heavy lead of appliances.

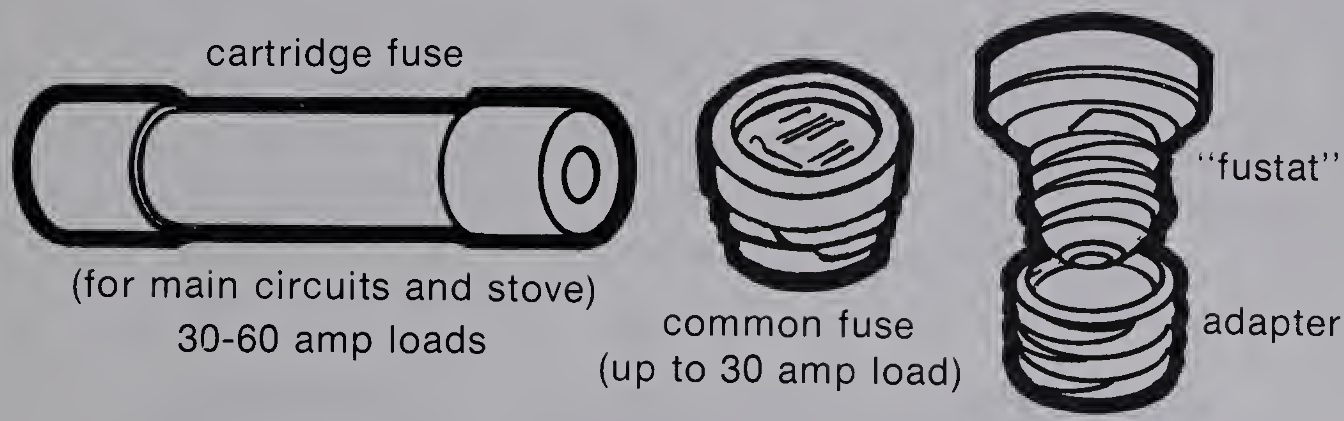
★ **5–5. How does the size of the wiring in a home affect the number of appliances that can be used?**

Too many appliances on a wire that is too thin spells d-a-n-g-e-r. Too many appliances on a single circuit in a house can do the same thing. The wire inside the wall could melt. This breaks the circuit, and the current stops. Sometimes the wire overheats and causes a fire. Unless you are lucky, you could burn the house down.



The *National Electrical Code,* which tells electricians how houses should be wired, does not trust to luck. It specifies that every branch circuit must be protected by a fuse or a circuit breaker.

A fuse is just a small piece of wire mounted in a holder. All the current in the branch circuit has to pass through the fuse. If the current gets too great, the fuse melts. This breaks the circuit. There is no longer any current in that branch. After the overload has been corrected, the fuse must be replaced.

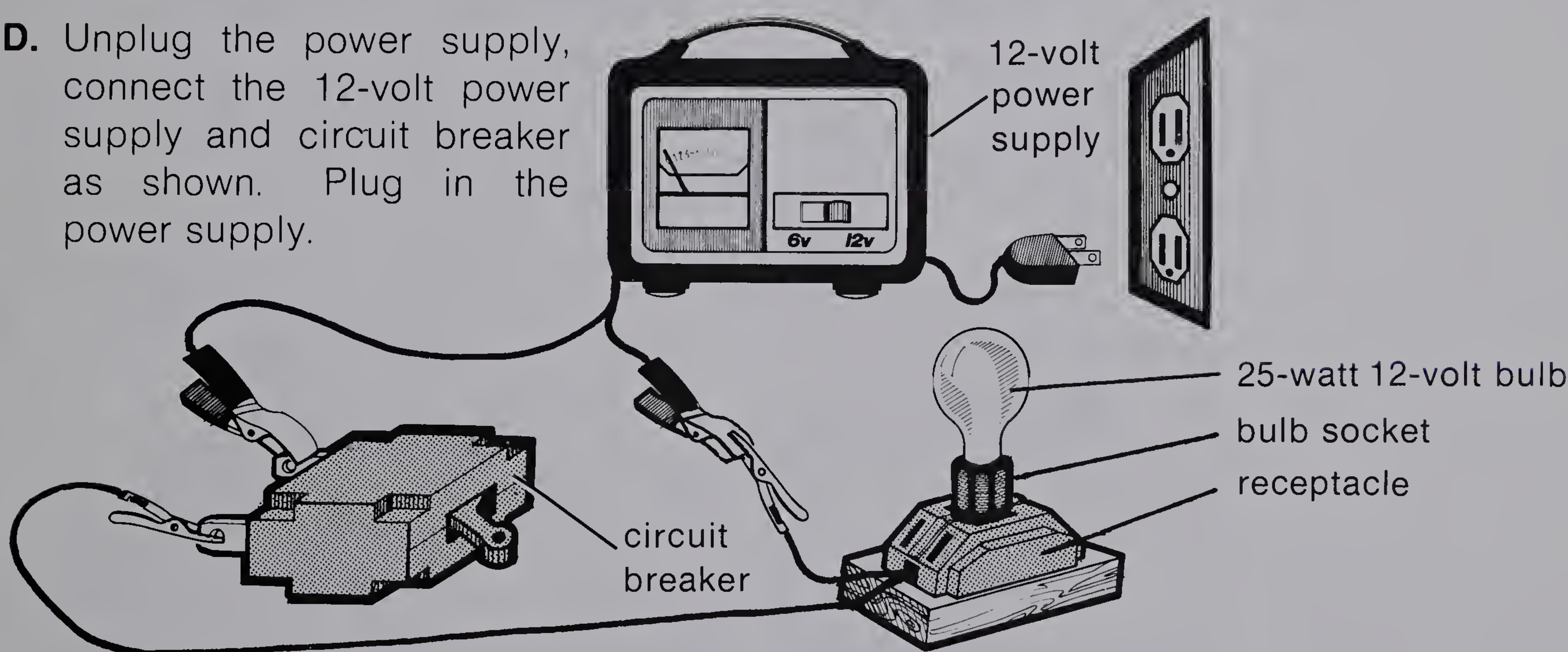


• 5–6. Household fuses have a little window so that you can see the fuse wire. Why is that a good idea?

5-6. You can see whether the fuse has blown.

A circuit breaker does the same sort of thing as a fuse. But, it looks like a switch, and you can use it like a switch to turn off the current. It can also turn itself off. Test one to see.

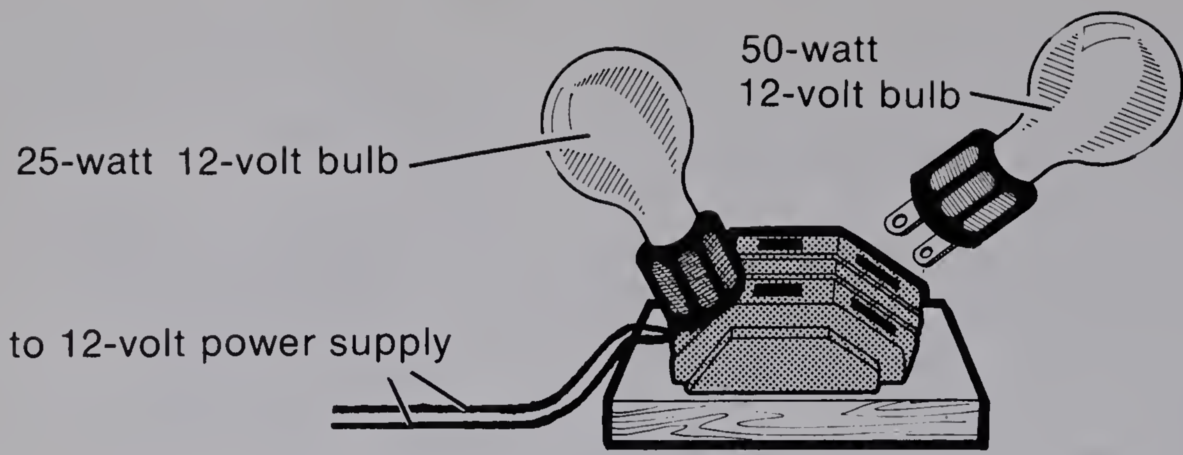
D. Unplug the power supply, connect the 12-volt power supply and circuit breaker as shown. Plug in the power supply.



Each 25-watt bulb uses 2 amperes of current. Two 25-watt bulbs use twice as much or 4 amperes. The current that flows through the circuit breaker is the sum of currents flowing through all bulbs that light. Thus, if a 25-watt and 50-watt bulb are both plugged in and lit, 2+4 or 6 amperes of current flow through the breaker.

• 5–7. How much current is drawn by two 50-watt, 12-volt bulbs?

5-7. 8 amperes

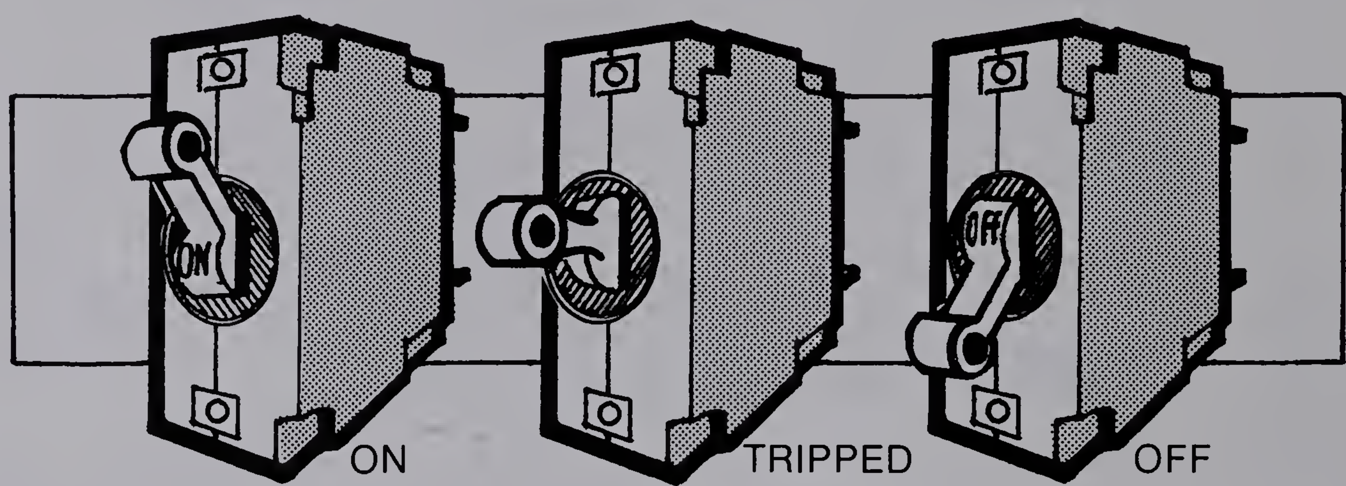


E. Plug in additional bulbs to find out what happens with the following bulb combinations:
two 25-watt bulbs;
one 25-watt bulb and one 50-watt bulb;
two 50-watt bulbs.

5-8. 6 amperes

• 5–8. How many amperes overload the circuit?

A circuit breaker must always be reset before the circuit can be used again. Some breakers do not go to the *off* position when they trip. To reset one of those, you must first move it all the way to *off*, and then back to *on*.



The "brain" of a circuit breaker is a bimetallic [by-ma-TAL-ik] strip. See Figure 5–3. Just like a fuse wire, this strip gets hot if there is too much current in it. But it does not melt.

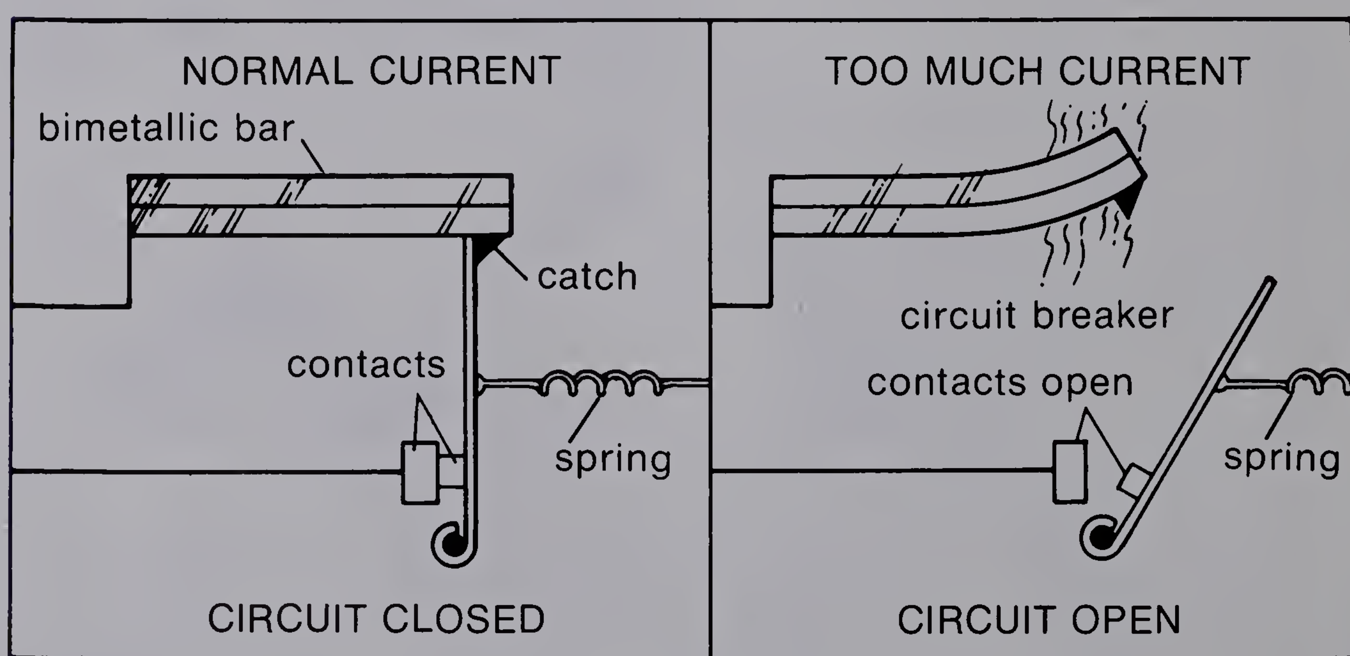


Figure 5–3

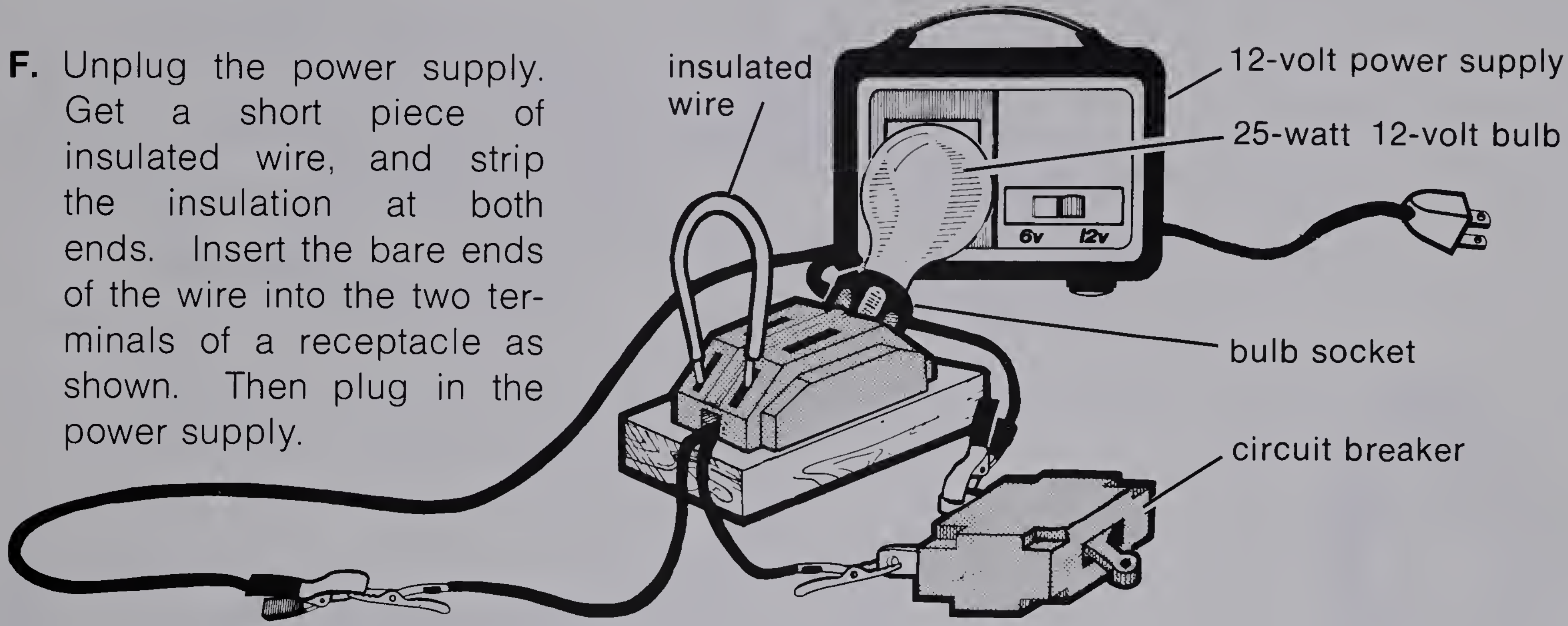
5-9. When the bimetallic strip gets hot, it bends and opens the circuit at the contact points.

• 5–9. Look at Figure 5–3. Then explain how the bimetallic strip breaks the circuit if there is too much current in it.

It takes a little while for the bimetallic strip to heat up. That's important because there is always a large surge of current when any motor is turned on. The circuit breaker waits a little while before tripping. If it did not, it would trip every time you turned on a motor.

But sometimes it is not safe to wait. If insulation is frayed or a wire comes loose, there may be a short circuit in the system. See what happens to the circuit breaker then.

F. Unplug the power supply. Get a short piece of insulated wire, and strip the insulation at both ends. Insert the bare ends of the wire into the two terminals of a receptacle as shown. Then plug in the power supply.



• 5–10. What happened when you plugged in the power supply?

5-10. The circuit breaker tripped immediately.

It would be extremely dangerous to do Step F using a wall outlet. But it was safe here because the receptacle was not plugged into an outlet. It was connected to a 12-volt power supply. What you did was make a direct wire connection from a high voltage wire to a grounded, neutral wire. This is an example of what is meant by a *short circuit.*

When there is a short circuit, there is nothing to prevent enormous current from flowing from hot to ground. The circuit must be broken immediately. A fire could start in the walls before the bimetallic strip heats up. That's the reason the circuit breaker contains a magnetic tripping device in addition to the bimetallic strip. The current goes through an electromagnet. If there is too much current, the magnetic force gets strong, and it trips the breaker.

• 5–11. Explain what is meant by a *short circuit.*

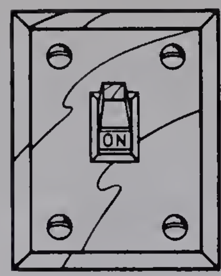
5-11. A short circuit is a direct connection between high voltage and ground by a good conductor such as a wire.

★ **5–12. A circuit breaker or fuse prevents fire by opening the circuit when there is too much**
a. voltage.
b. noise.
c. light.
d. current.

5-12. d

ACTIVITY EMPHASIS: The current used by an appliance can be found from the equation amperes = watts ÷ volts. The proper electrical requirements of an appliance can be determined from a label usually on the back of the appliance or from the type of plug used by the appliance.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.
See also Advance Preparation, p. TM 5.



Activity 6
Matching Appliances to Circuits

The television set shown in Figure 6–1 is listed and labeled by the Underwriters Laboratories. That means it has been tested and found to be safe. It meets all national standards. The label also gives you information about the kind of household circuit on which the set must be used.

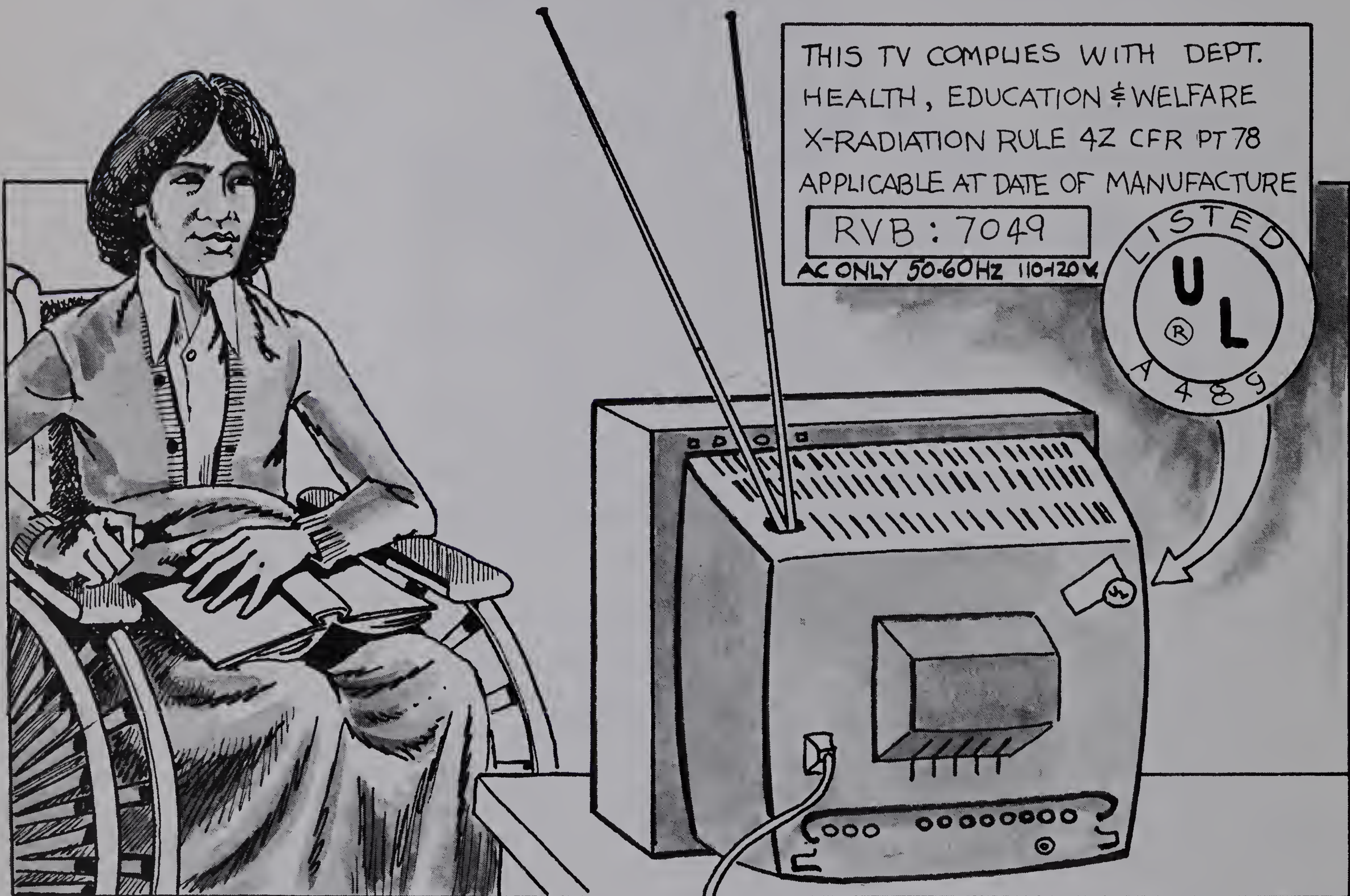
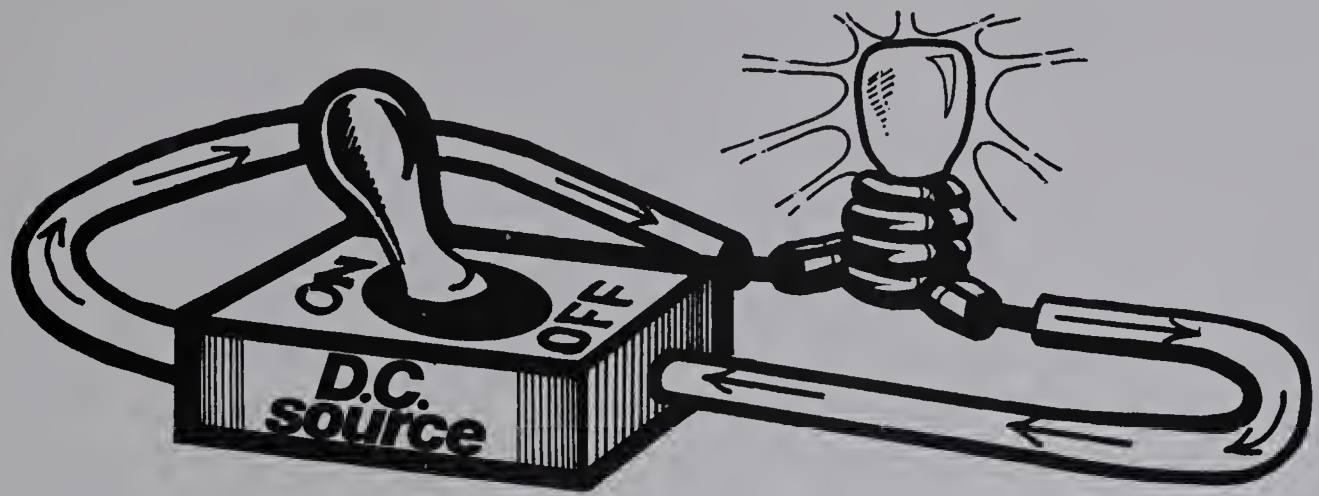


Figure 6–1

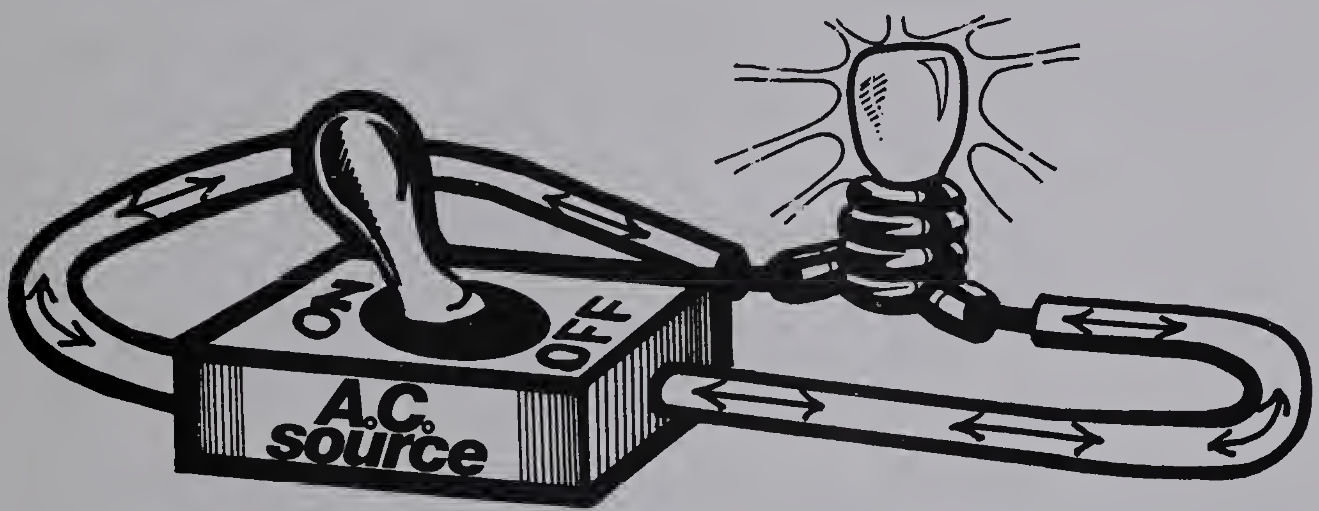
The tag says "AC only." In the oldest household wiring, the electrons flowed continuously in one direction. This type of current is called *direct current* or *DC*. There are very few homes where DC is still used. If your home or camper uses DC, you cannot use the TV set shown in Figure 6–1.

AC means *alternating current*, which nearly everyone now has. In alternating current, the electrons flow first one way and then the other. They change direction many times a second. The TV set in Figure 6–1 can be used only if the house is wired with AC.



★ **6–1. Why do you have to be very careful to read labels on appliances if your house has DC power?**

6-1. Many appliances cannot be used on DC and are labeled "AC only."



• 6–2. What difference is there in the way AC and DC currents flow?

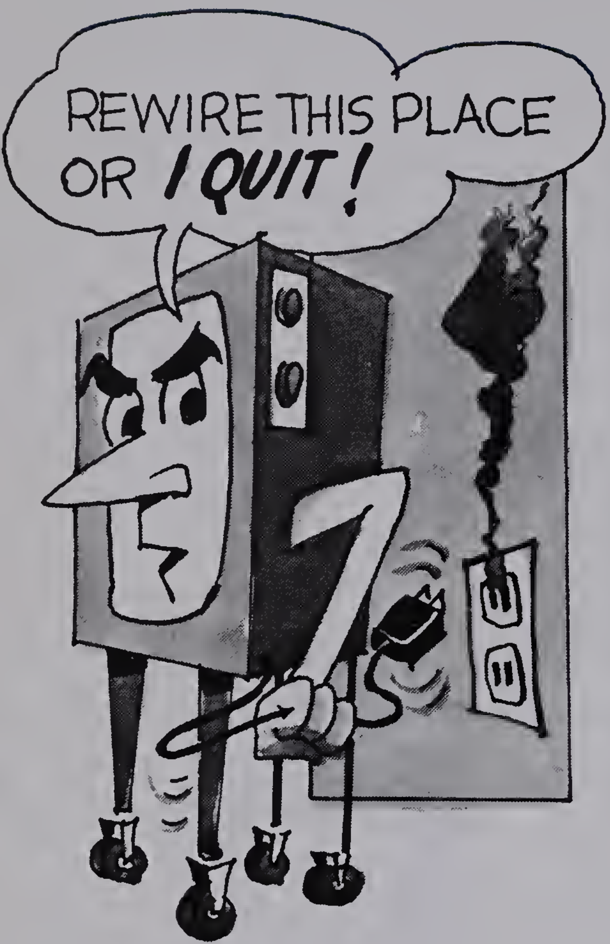
6-2. For DC, current flows in one direction; for AC, current changes direction.

The tag in Figure 6–1 also says "50–60 Hz." This refers to the *frequency* of the alternating current—how often it changes direction. Sixty hertz (Hz) means it goes through sixty complete cycles of direction change every second. Most of the AC in the United States and Canada is 60 Hz, but in some places it is 50 Hz.

Many 60-Hz appliances work equally well on 50 Hz. Electric clocks and record and tape players are among the important exceptions. Their frequencies must be matched.

The tag also says "110–120 volts." The TV set is designed to operate on a circuit that supplies electricity at a voltage of between 110 and 120 volts. That is the range of most general-purpose branch circuits in American homes. The TV set can be plugged in anywhere in such homes. It may not work at all below 110 volts. And if you plugged it into a line with higher voltage, the set would probably burn out.

6-3. The 12-volt bulb would burn out (or explode) in the 110-volt circuit.



★ **6–3. Why can't a 12-volt light bulb operate in a regular home ceiling or closet bulb socket?**

American homes have special 220-volt lines for heavy-duty appliances. Clothes driers, large air conditioners, stoves, and water heaters are examples. These appliances will not work on an ordinary branch line. If you want to buy a room air conditioner to be plugged into a general-purpose circuit, you must be sure that it is rated at 110–120 volts. A 220-volt unit would have to have a special branch circuit installed.

Finally, the tag in Figure 6–1 says "360 watts." If the voltage and frequency ratings of the TV set match your house circuit, you can use the set. But you may not be able to plug it in just anywhere. You have to know that the branch circuit into which you put it can supply enough current. To find out, use the power rating of the set—360 watts.

What that means will not be discussed here. If you want to know more about it, do Activity 11. But even without knowing what it means, you can use the rating to find out how much current the appliance requires. This is the rule:

$$\text{current (in amperes)} = \frac{\text{power (in watts)}}{\text{voltage}}$$

$$\text{or amps} = \text{watts} \div \text{volts}$$

For example, the current drawn by the TV set is

$$\frac{360 \text{ watts}}{120 \text{ volts}} = 3.0 \text{ amperes}$$

6-4. $\frac{60 \text{ watts}}{120 \text{ volts}} = 0.5$ amperes

★ **6–4. How much current is drawn by a light bulb rated at 120 volts, 60 watts?**

The total current in any branch circuit can be determined by adding up the currents used by each appliance on the circuit. Most general-purpose branch circuits can supply 15 amperes. If the current is more than that, the fuse will blow or the circuit breaker will trip.

6-5. (a) 1.00; (b) 0.10; (c) 0.50; (d) 7.00; (e) 2.00; (f) 1272; (g) 10.60.

★ **6–5. Figure 6–2 gives the power ratings of all the electrical appliances now on a 120-volt branch circuit. In your notebook, record the missing information for items a–g. The totals in this table show the current drawn by all of them.**

APPLIANCE POWER RATING DATA

APPLIANCE	POWER RATING (in watts)	CURRENT (in amperes)
Floor lamp	120	(a)
Clock	12	(b)
Table lamp	60	(c)
Electric heater	840	(d)
Wall fixture	240	(e)
Total	(f)	(g)

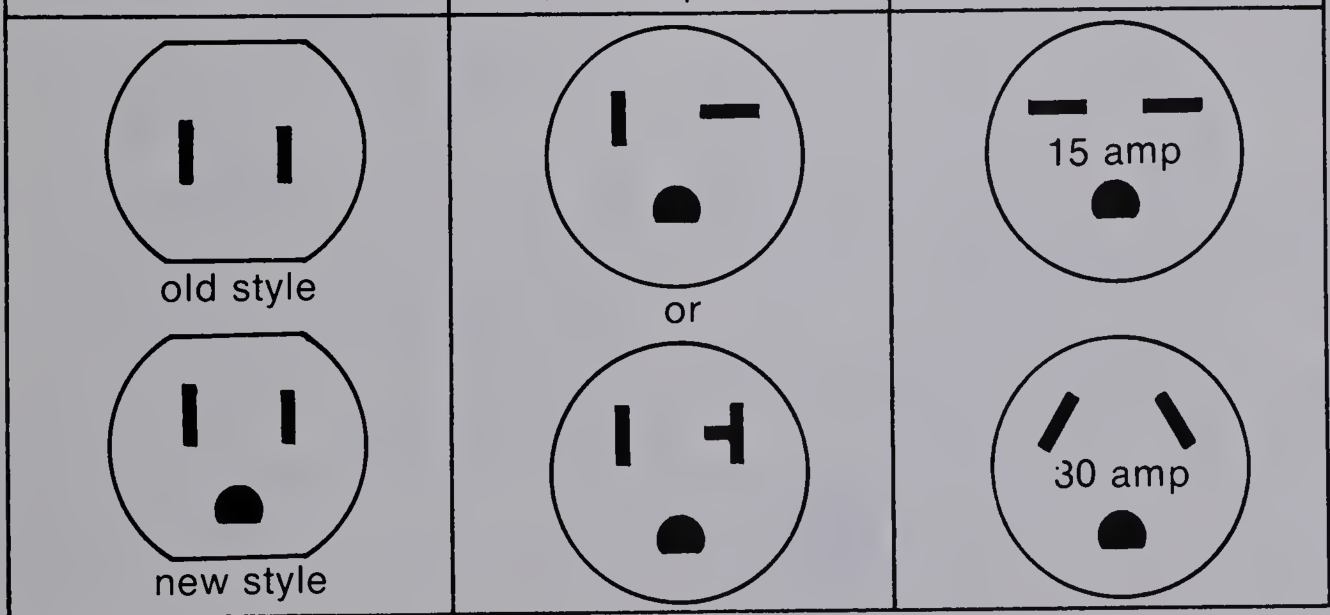
Figure 6–2

- 6–6. Can you add a 360-watt TV set to the circuit in Question 6–5 without blowing the fuse or tripping the circuit breaker?

6-6. Yes. The TV pulls 3.00 amps and the total current will not exceed the 15 amp total capacity.

The *National Electrical Code* rules provide a way of matching appliances to circuits so that you are not likely to plug in an appliance where it doesn't belong. The method is to use a different kind of plug for each type of circuit.

These receptacles are used on ordinary 110-volt, 15-ampere lines.	These receptacles are used for high-power equipment on 110-volt, 20-ampere lines.	These receptacles are used on 220-volt lines.

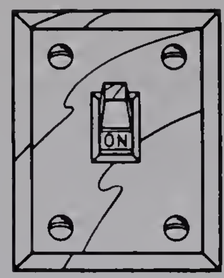


- 6–7. Explain why you should never change the plug of an appliance to a different type of plug.

6-7. Each different socket indicates a different branch-circuit ampere limit. By switching plugs on appliances, you may overload the circuit.

ACTIVITY EMPHASIS: There are five recommended steps to follow when someone has received an electric shock.

MATERIALS PER LAB GROUP
None.
See also Advance Preparation, p. TM 5.



Activity 7
First Aid for Electric Shock

Hopefully, you'll never touch a wire to find out whether there's an electric current in it. But sometime, someone near you might accidentally let electricity take a shortcut through his or her body into the ground. If the person collapses, you'll need to act fast.

Shocked lineman revived

By GREG DAUBER
Democrat Staff Writer

Two co-workers used mouth-to-mouth resuscitation and chest massage to bring Charles Hevard back to life Thursday after 7,200 volts of electricity jolted him.

Hevard, foreman of a city line crew, was sliding a rubber insulator sleeve over a mechanical jumper when his left hand slipped, said Pete Koikos, city superintendent of electrical transmission and distribution.

Hevard was wearing rubber gloves but his unprotected left elbow touched a conductor and the charge went through his body and out his left leg, said Tim Hartsfield, the co-worker who performed the artificial respiration.

While he was working on overhead lines from the bucket of a city "cherry-picker," Hevard's left leg apparently touched a drill in the floor of the bucket, attached by a cord to the truck, which served as the ground.

The jolt knocked Hevard back into the bucket, Hartsfield said.

Other co-workers told Hartsfield of the accident and he jumped on the controls to bring the bucket down.

Hartsfield, H.B. Roberts, the co-worker who did the chest massage, and another dragged Hevard from the bucket and went to work on him.

Hevard started breathing and talking about a minute after the electricity jolted him, Hartsfield estimated. His heart, which had stopped, began to beat.

Hevard was taken to Tallahassee Memorial Hospital where Thursday night he was in intensive care but listed in good condition. He had two-inch black burns on his elbow and leg but his heartbeat was normal.

If you saw a scene like Figure 7–1, would you know what to do? Think! Don't do anything to endanger your own life. You won't be much help if you get yourself shocked too.

Figure 7–1

STEP 1

The first thing to do is to shut off the electricity if you can do it quickly. But you have to move fast!

STEP 2

If you can't shut off the power, be extremely careful not to handle the injured person directly. You'll have to find some other way to move him or her away from the shock hazard.

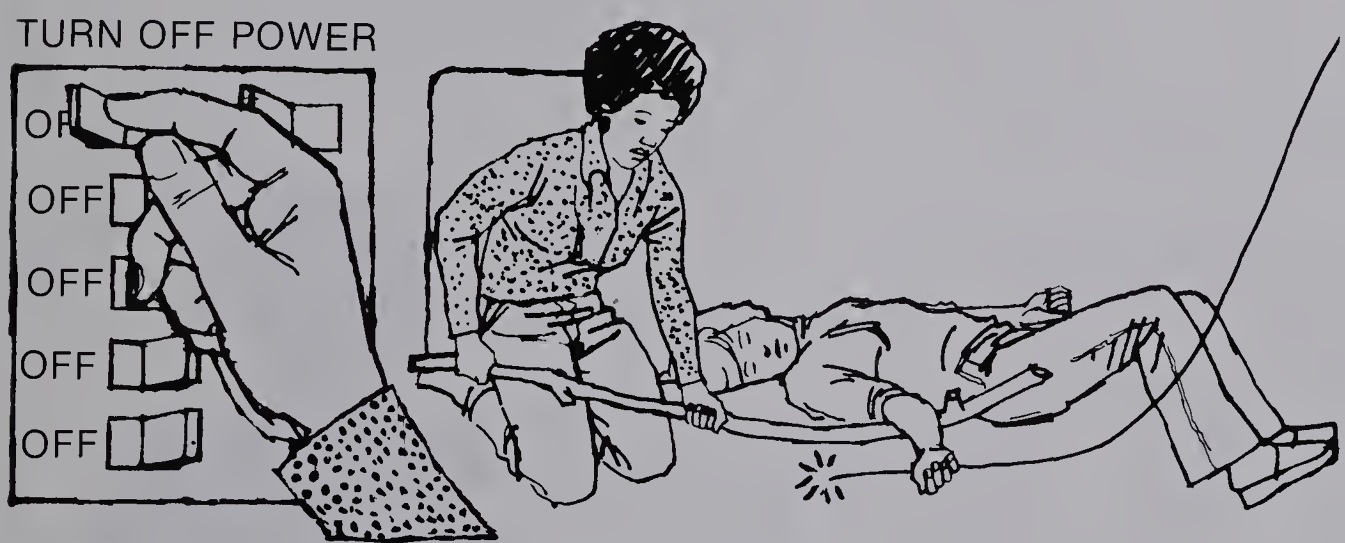


Figure 7–2

★ 7–1. How can you avoid endangering your own life while you're trying to help an injured person experiencing electric shock?

7-1. Don't touch the injured person as long as he or she is in contact with high voltage.

A dry stick is being used in Figure 7–2 to move the person. You should never use a metal pole to move the victim away from the wire. You do the victim no good if you get yourself electrocuted. Use a dry pole of some kind such as a broom handle.

★ 7–2. It would make more sense in Figure 7–2 to move the wire and not the victim. Should you use a dry wooden pole? Explain your answer.

7-2. Yes. A dry wooden pole is not an electrical conductor.

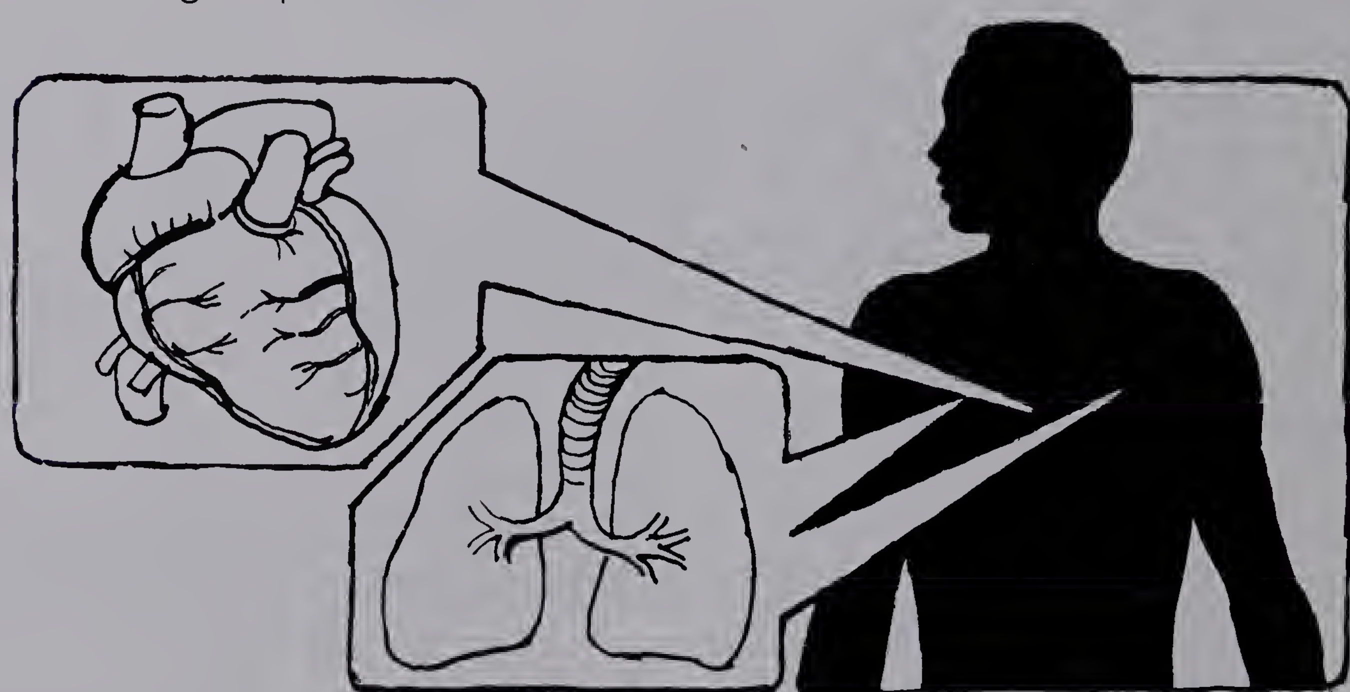
STEP 3

Get help! While you help the victim, send someone to call the police or fire department emergency number. In many places, the number to call is 911.

7-3. Answers will vary, but many are now 911.

• 7–3. What is the emergency number in your community? (Memorize it!)

There are two dangerous effects that electric shock has on the body. It may disrupt the heartbeat so the heart just squirms instead of beating regularly. Or it may paralyze the breathing muscles so breathing stops.



Either of these effects will stop the flow of oxygen to the body cells. The brain needs a lot of oxygen. If its supply of oxygen is not restored within about four minutes, the brain will be permanently damaged and the victim may die.

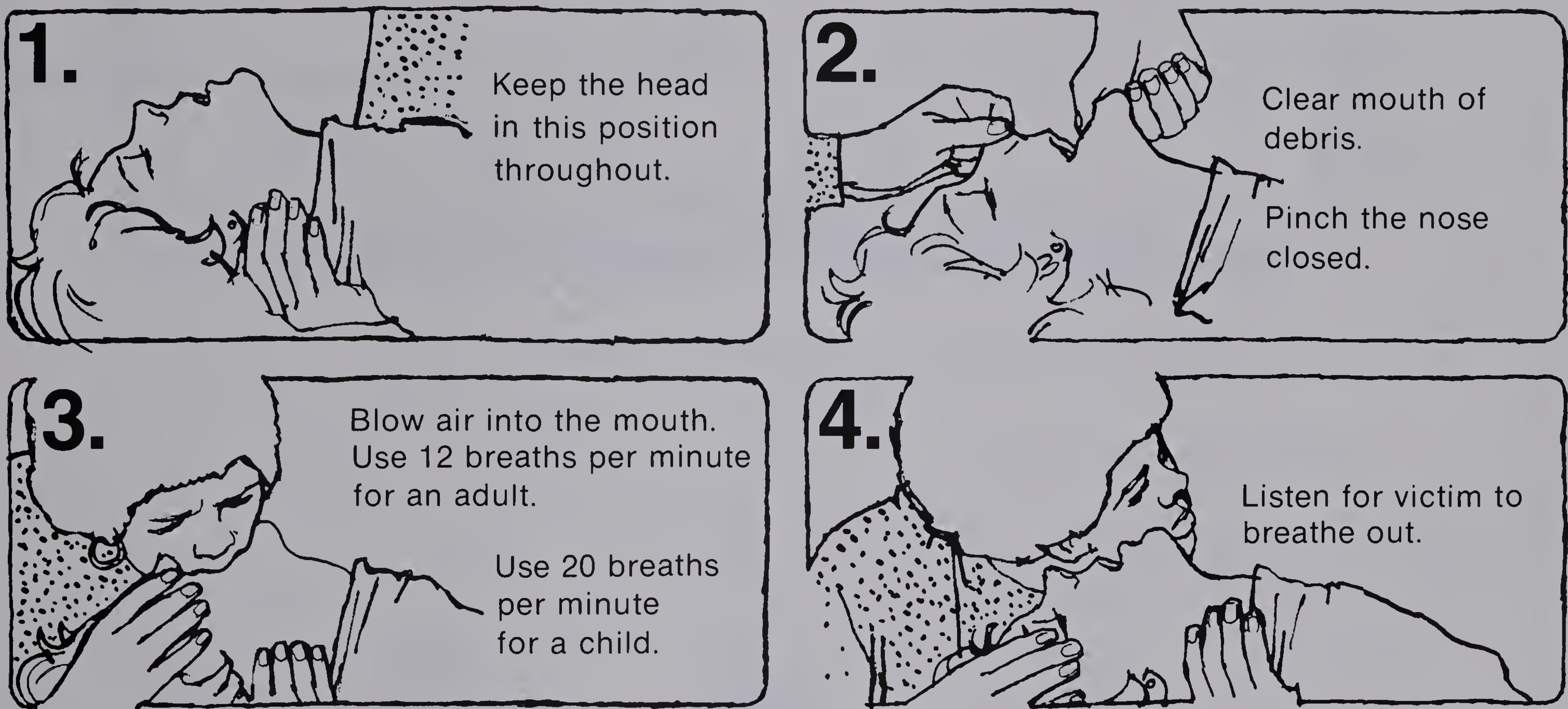
7-4. The brain can be permanently damaged if it goes without oxygen for more than four minutes.

• 7–4. Why is it necessary to act fast if you want to save the victim of an electric shock?

STEP 4

If the injured person is unconscious and not breathing, you'll have to administer artificial respiration, probably for a long period of time. Also check for pulse. It may be that heart massage is needed at the same time.

This activity does not go into detail on artificial respiration or heart massage. If you want more information, check the most recent edition of *First Aid*, published by the American Red Cross. You might even want to sign up for a first-aid course offered in your school or community.



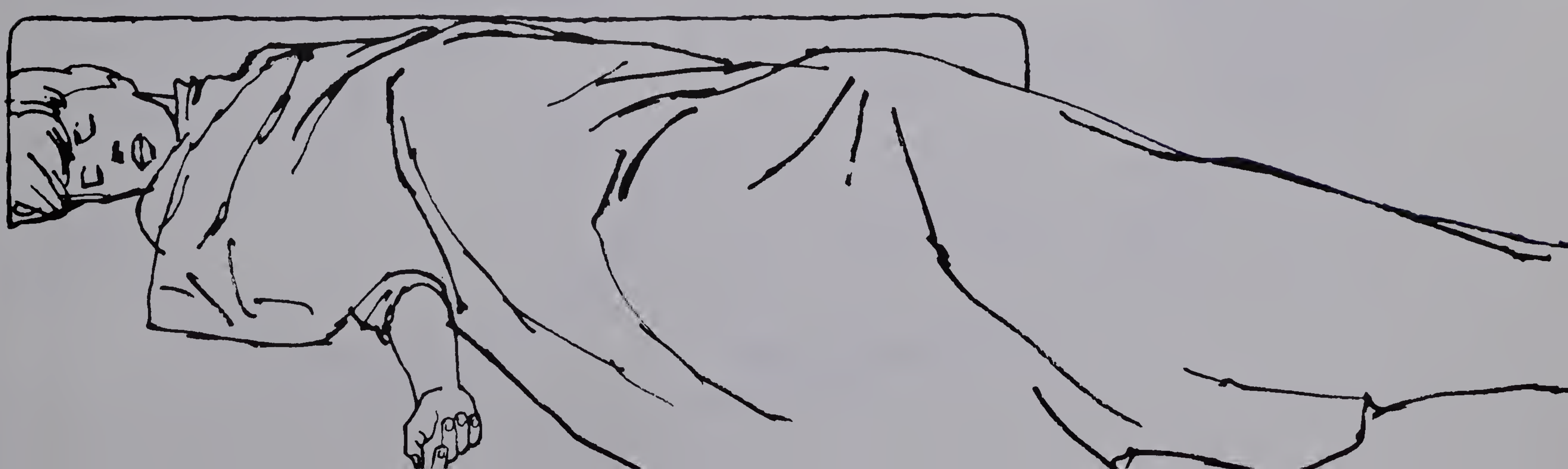
★ 7–5. What would you do for the shock victim if you didn't know how to give artificial respiration?

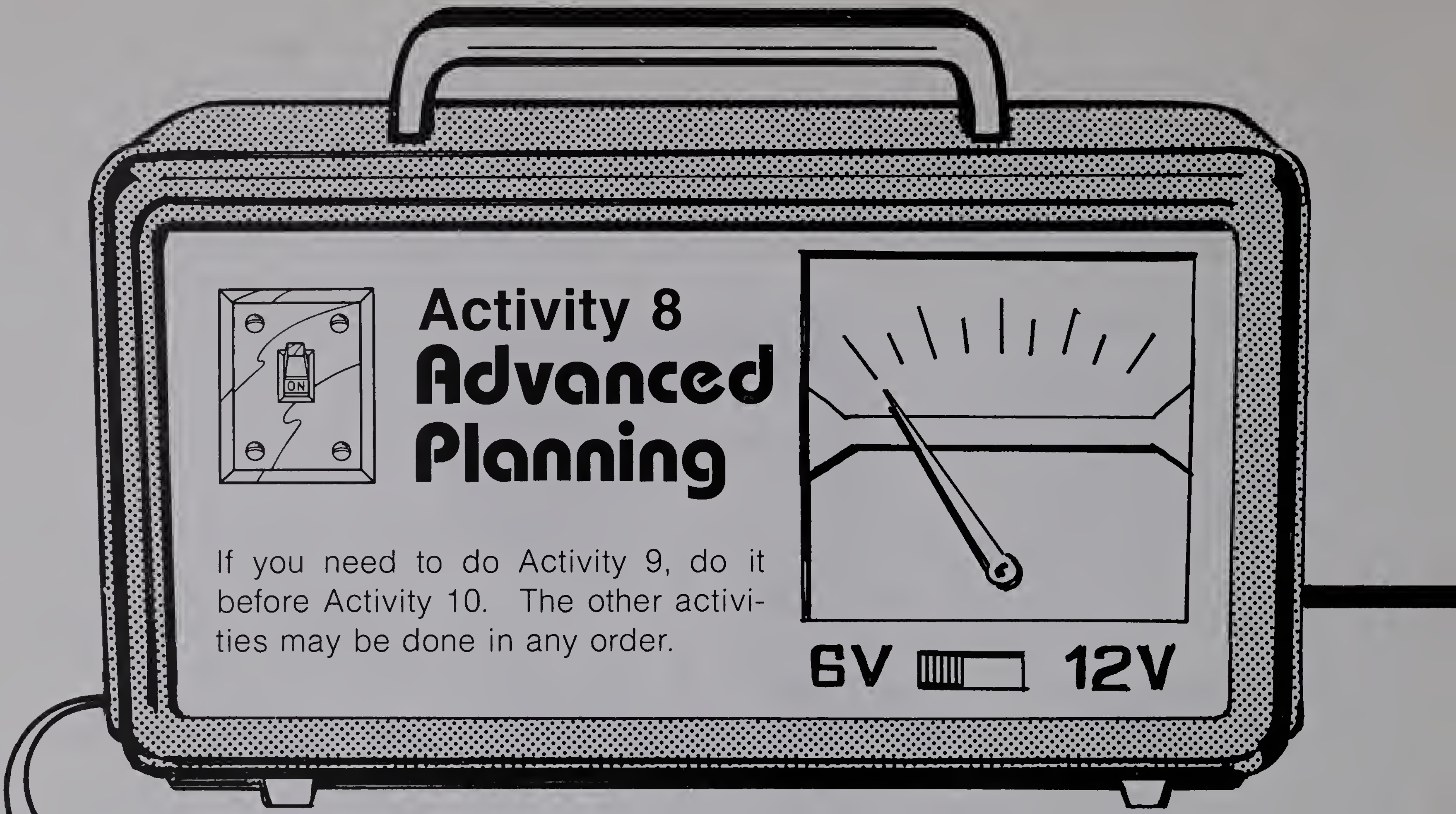
7-5. Get someone who does.

STEP 5

When the patient is breathing, keep him or her warm and quiet until the doctor or ambulance arrives.

With a cool head and some common sense, you might be able to save someone's life.





Activity 8
Advanced Planning

If you need to do Activity 9, do it before Activity 10. The other activities may be done in any order.

Activity 9 Page 42

Objective 9–1: Define electric current and electric charge.

Sample Question: Match the terms electric current and electric charge with the appropriate statement.

Term

a. electric current

b. electric charge

Statement

1. electronic pressure

2. number of coulombs

3. rate of flow of volts

4. rate of flow of coulombs

Objective 9–2: Measure electric current and calculate electric charge.

Sample Question: If there are 3 amperes of current in a circuit, calculate the number of coulombs that flow by in 5 seconds.

Activity 10 Page 47

Objective 10–1: Define and measure voltage.

Sample Question: What is voltage?

a. energy per coulomb of charge

b. a measure of power

c. the number of coulombs

d. potential of each electron

Objective 10–2: Define and calculate energy and power.

Sample Question: A floodlight is rated at 1200 watts. How much energy does it use in 1.5 minutes?

Activity 11 Page 54

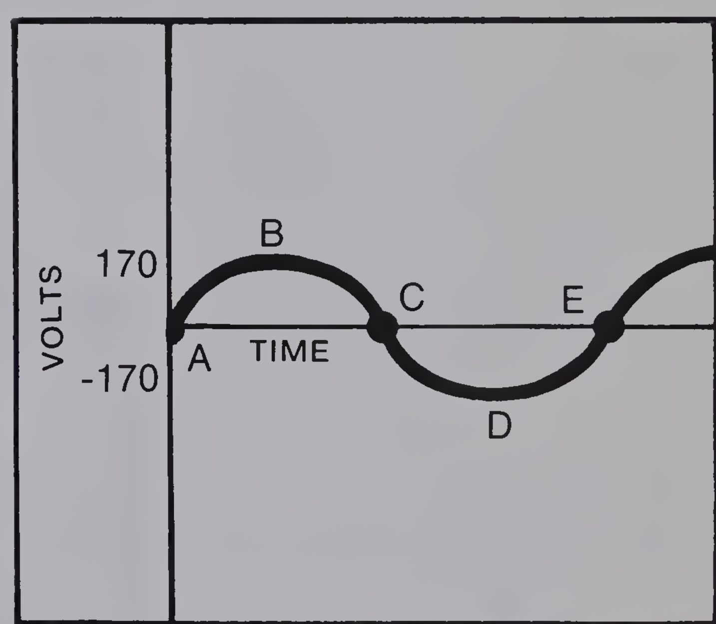
Objective 11–1: Define electrical resistance and use Ohm's Law to solve problems.
Sample Question: What is the resistance of a light bulb operating at its rated value of 12 volts, 25 watts?

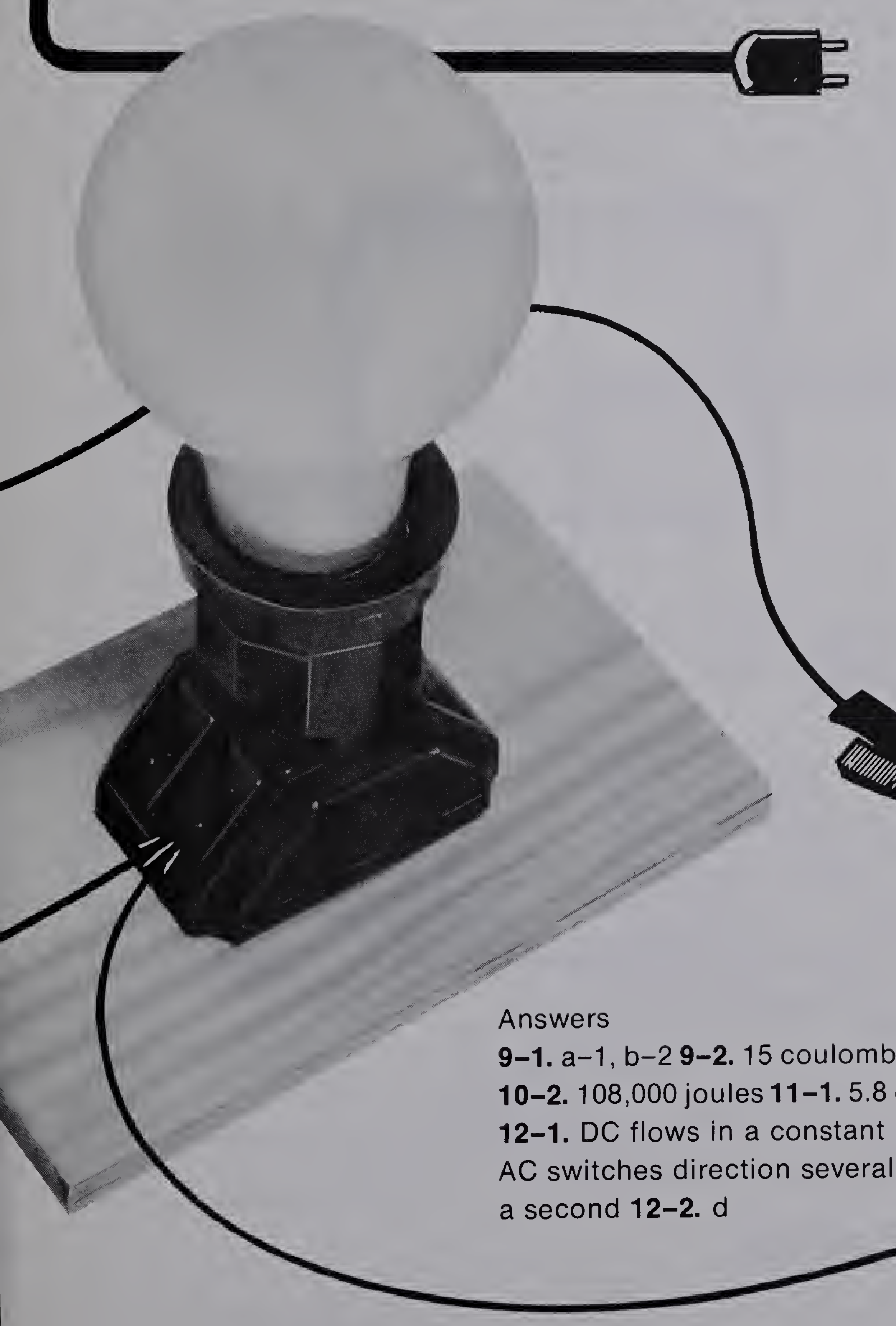
Activity 12 Page 59

Objective 12–1: Describe the difference between AC and DC current and potential and explain why AC is so widely used.
Sample Question: How does the potential differ between AC and DC sources?

Objective 12–2: Using graphs of potential or current and time, identify points of maximum and minimum potential or current.
Sample Question: Identify by letters the points on the graph where the voltage is minimum.

TIME/VOLTAGE RELATIONSHIP





Answers
9–1. a–1, b–2 **9–2.** 15 coulombs **10–1.** a
10–2. 108,000 joules **11–1.** 5.8 ohms
12–1. DC flows in a constant direction, AC switches direction several times a second **12–2.** d

ACTIVITY EMPHASIS: An ammeter is used to measure electric current. Electric current (I) is the amount of charge (Q) per unit time (t). $I = Q \div t$.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.

9-1. A power supply.

A bulb.

A circuit breaker.

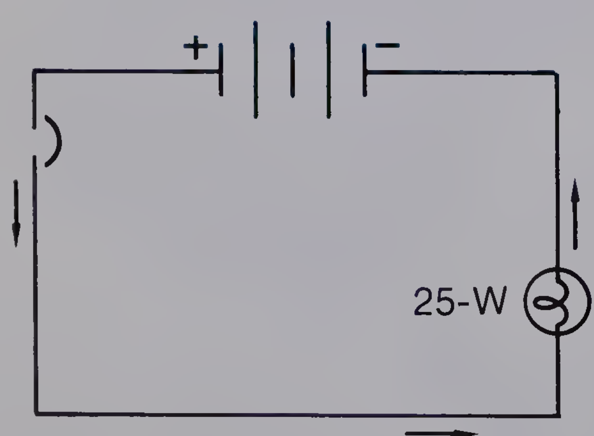
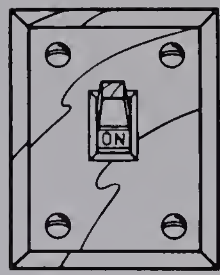


Figure 9–2



Activity 9
Measuring Electricity

Many cars have a dial on the dashboard indicating "charge-discharge." Others have a light marked *battery*. The behavior of those meters indicates the health of the car's electrical energy sources. Electricians use a more complicated meter to find out what's wrong with a circuit.

Figure 9–1 shows a circuit that will supply electric current to a bulb. You can easily trace the current path, or circuit. From the red (+) terminal of the power supply, electricity flows through the circuit breaker, through the bulb, and then back to the power supply. Figure 9–2 is a way to show that circuit. It is called a circuit diagram.

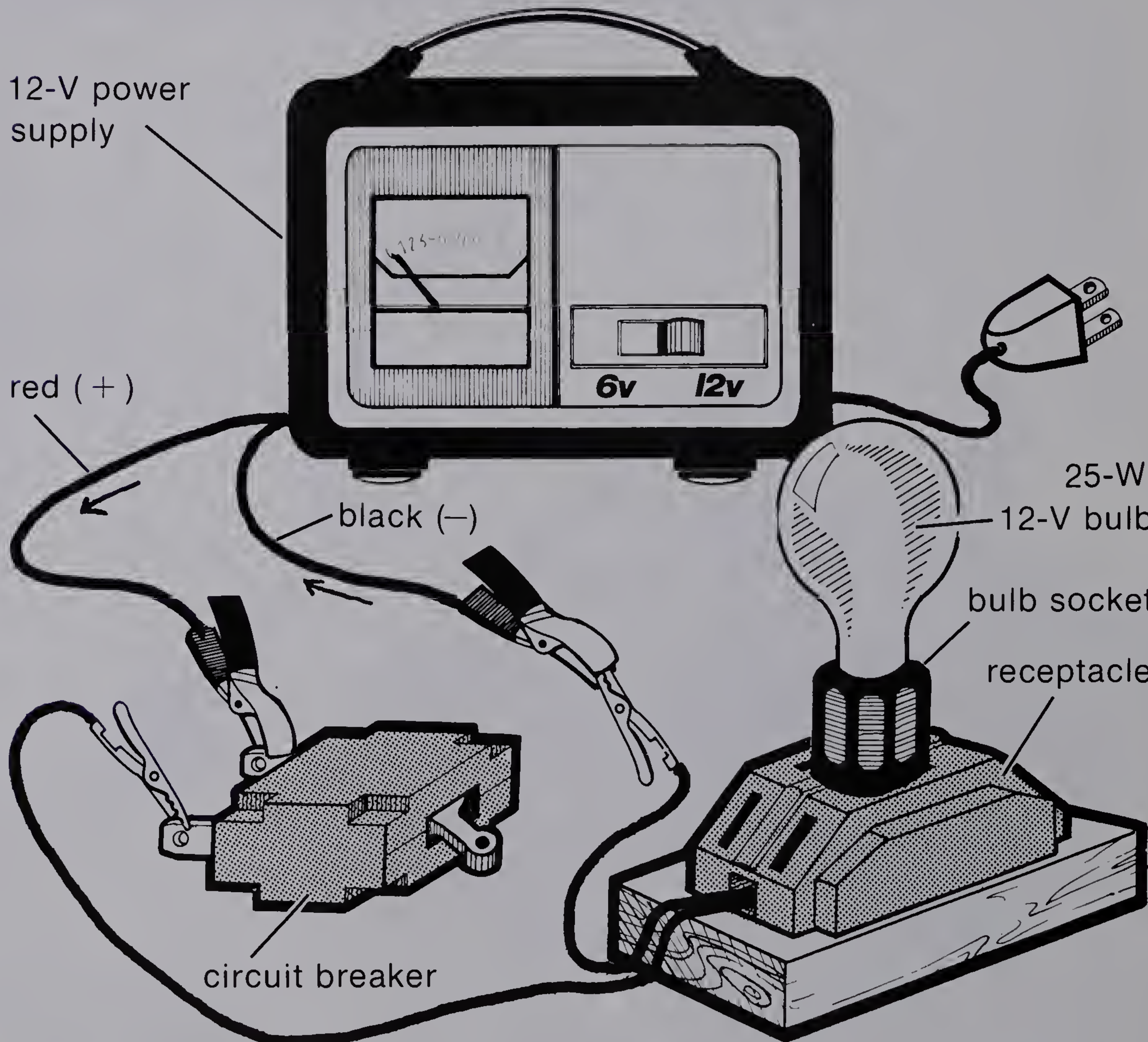


Figure 9–1

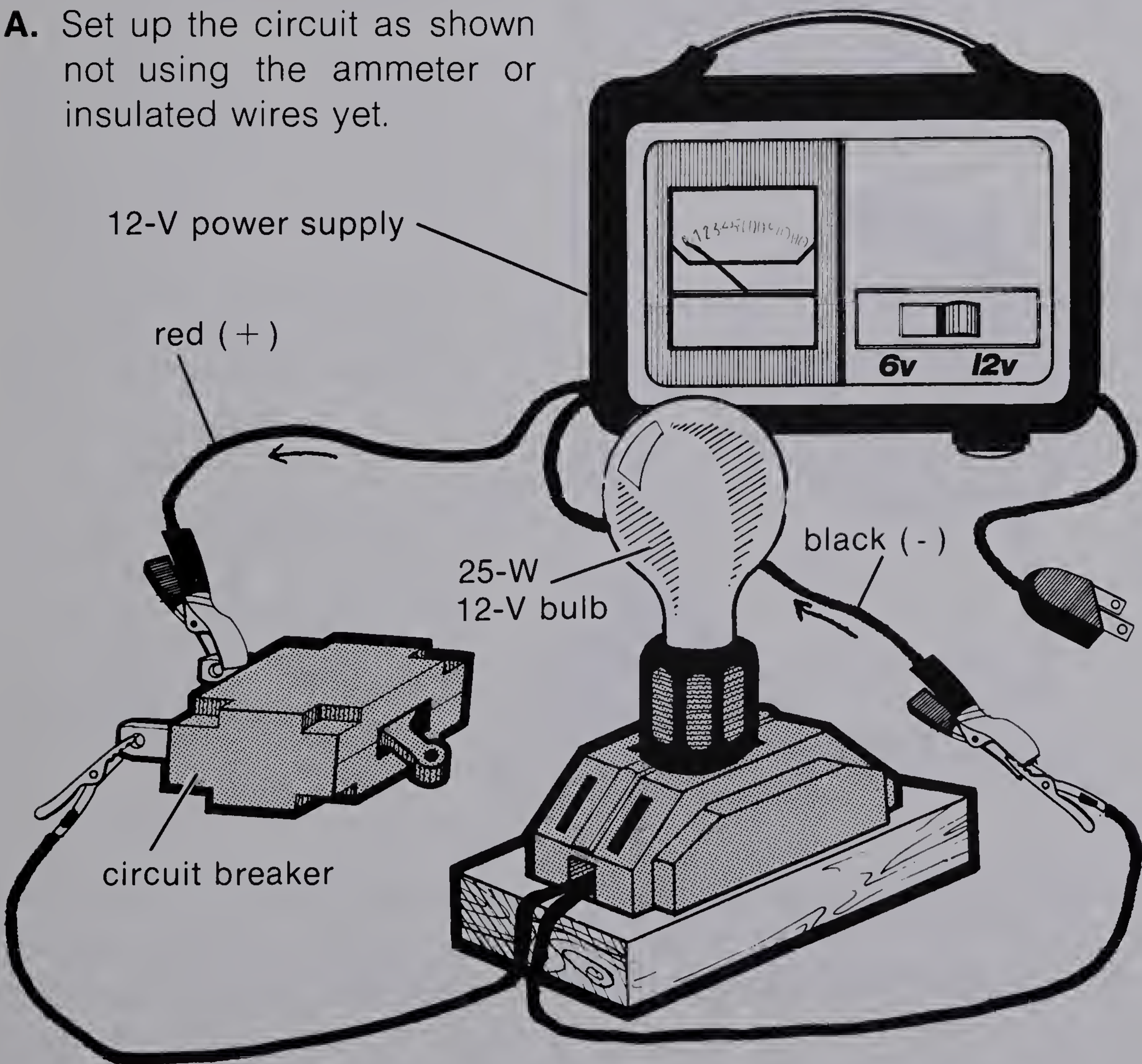
- 9–1. Compare Figure 9–1 with the circuit diagram in Figure 9–2. Then draw the circuit diagram symbol for a power supply, a bulb, and a circuit breaker.

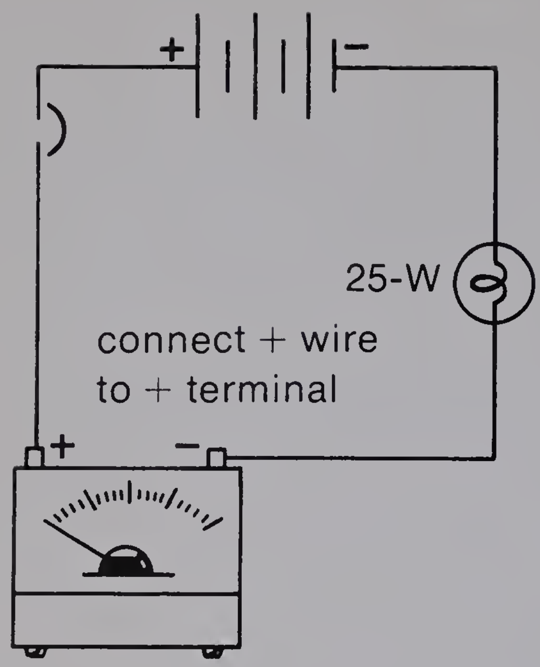
There are two kinds of meters—ammeters and voltmeters. You can use an ammeter to measure how much current is in a circuit. To find out how the ammeter is used, you will need the following materials.

power supply, 12-V DC
bulb socket
bulb, 25-W, 12-V
circuit breaker, 5-A
3-outlet receptacle
ammeter, about 5-A AC
2 20-cm lengths of insulated wire

CAUTION **When hooking up an electric circuit, don't plug the power supply into a 110-volt outlet until all other connections have been made.**
Be sure your hands are dry when working with electricity.

A. Set up the circuit as shown not using the ammeter or insulated wires yet.

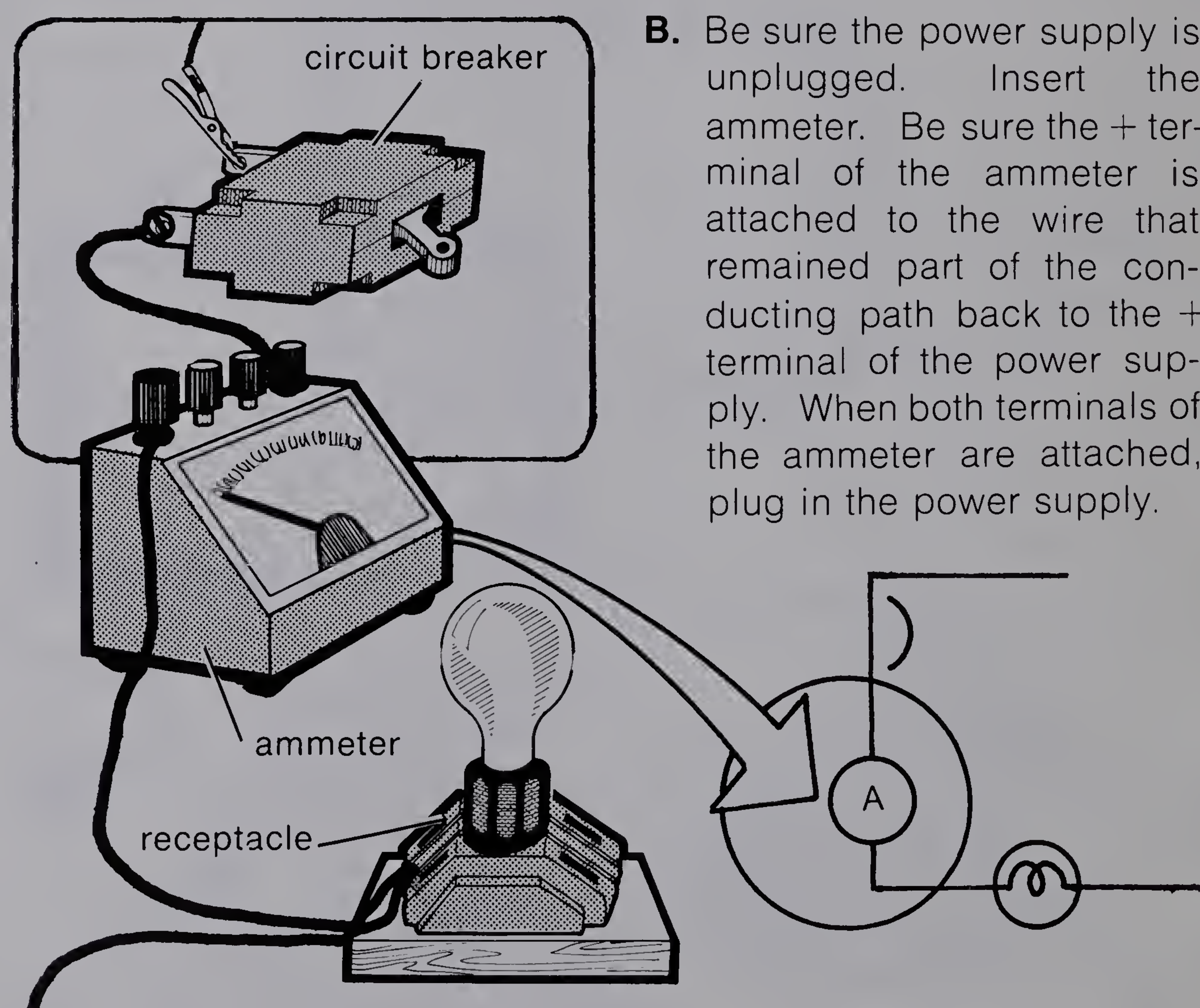




The terminals on the ammeter are marked differently. If the ammeter is connected into the circuit backwards, it can be damaged. Note which terminal is red, or +. The ammeter will be placed between the circuit breaker and the bulb. It will measure current there.

Use Figure 9–2 to trace the conducting path from the red, or +, terminal of the power supply to the point where you wish to insert the ammeter. Do this before actually connecting the ammeter.

CAUTION **Never connect an ammeter directly between the red (+) and the black (−) terminals of the power supply. An ammeter would behave as a short circuit, and carry current as easily as a copper wire. It can burn out.**



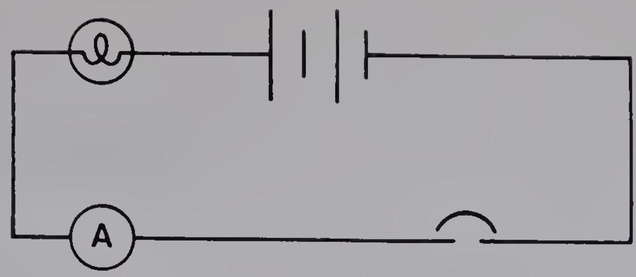
B. Be sure the power supply is unplugged. Insert the ammeter. Be sure the + terminal of the ammeter is attached to the wire that remained part of the conducting path back to the + terminal of the power supply. When both terminals of the ammeter are attached, plug in the power supply.

- 9–2. Draw the circuit symbol for an ammeter.
- 9–3. How much current is there between the circuit breaker and the bulb?

9-2. A 

9-3. 2 amperes

C. Now connect the ammeter to measure the current between the bulb and the power supply.



- 9–4. How much current is there here?

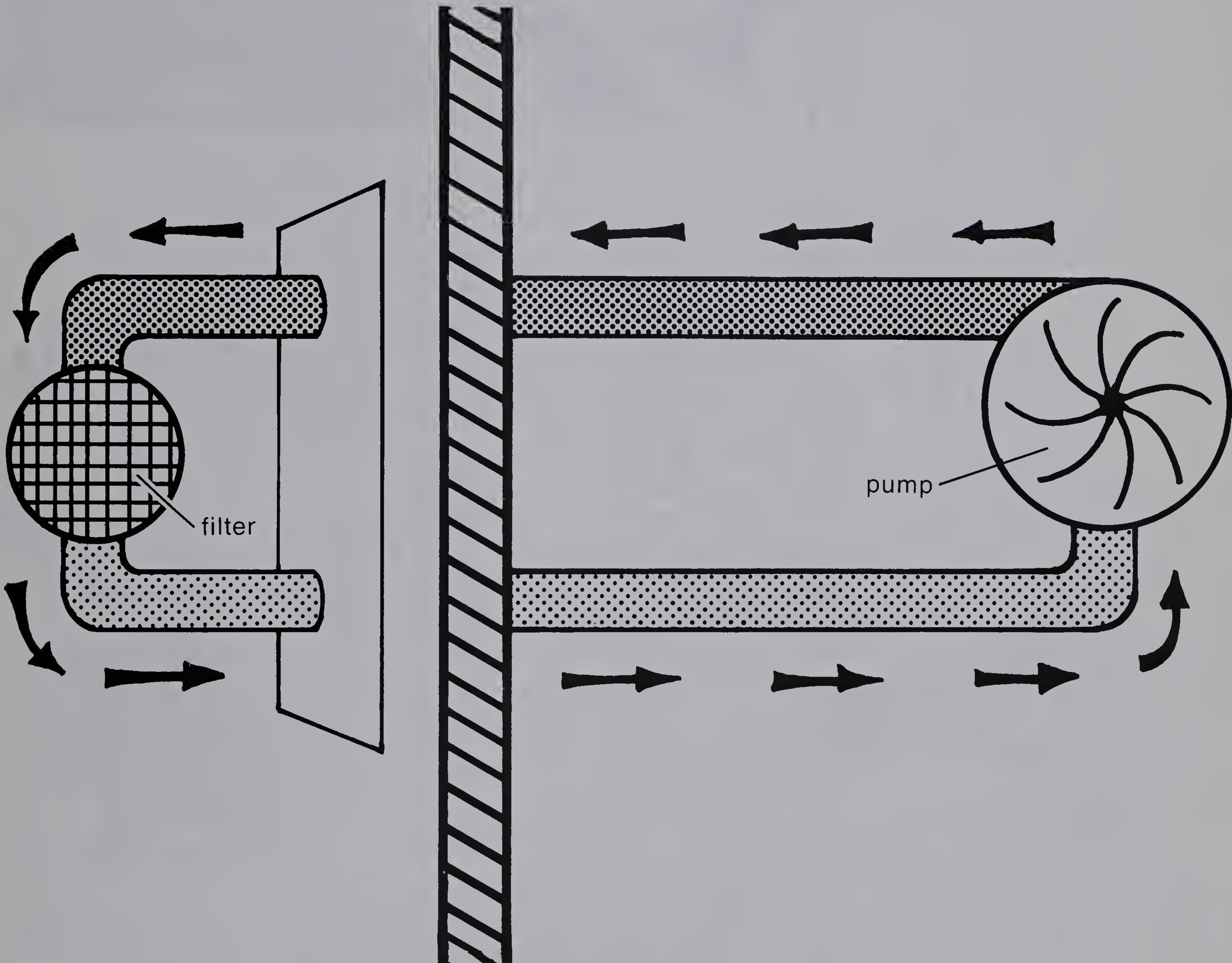
9-4. 2 amperes

- 9–5. How do the two currents you have measured compare? (See your answers to Questions 9–3 and 9–4.)

9-5. They are the same.

- 9–6. Was any current used in going through the bulb?

9-6. No.



A water circuit can help you to understand your answers. Suppose all the pipes are full of water. If water flows into any part of the circuit, just as much water must flow out the other side. There is no place for the water to go.

In the electric circuit, it is electrons that flow instead of water. Electrons have a property called *electric charge*. You can see the effects of this charge if you put some extra electrons on a comb by stroking it through your hair. The charge on the comb will attract tiny bits of paper.

When the current is in a wire, electrons flow through the wire. The ammeter measures the rate at which the electric charge flows through. The amount of charge in a wire is measured in *coulombs*. The coulomb is quite a large unit. It takes about 6.2×10^{18} electrons to have one coulomb of charge. When one coulomb of charge flows past a point in one second, the current is one ampere. This is a definition of an ampere. (Note: The number of electrons required to give 1 coulomb of charge is 6,200,000,000,000,000,000. This very large number can be written in scientific notation as 6.2×10^{18}. This shorthand is much easier to read.)

Suppose there is a current of 6 amperes in a circuit. How much charge flows in 10 seconds? By definition 6 *amperes* means 6 coulombs per second. Therefore, in 10 seconds, 60 coulombs will flow through the circuit. This problem can also be solved using a formula. Let I stand for current, Q for charge, and t for time. Recall the definition of current is $I = Q/t$. Then, the charge is $Q = It$. You might recall (Activity 6) that current also equals power (in watts) divided by voltage.

In the problem, then,

$$Q = It$$
$$Q = (6\ \text{A})\ (10\ \text{s})$$
$$Q = 60\ \text{coulombs}$$

9-7. Amperes must be found first.

$$I = \frac{\text{watts}}{\text{volts}}$$

$$I = \frac{25\ \text{watts}}{110\ \text{volts}}$$

$$I = 0.23\ \text{amperes}$$

then

$$Q = It$$

$$Q = (0.23\ \text{amps})\ (600\ \text{seconds})$$

$$Q = 138\ \text{coulombs}$$

9-8. Current is the amount of charge per unit of time.

★ 9–7. A light bulb rated at 110 volts, 25 watts is being used in its rated circuit. How much charge passes through the bulb in 10 minutes?

★ 9–8. How is *current* different from *charge?*

ACTIVITY EMPHASIS: Power (watts) is the amount of energy (joules) used per unit of time. P = VI. The voltmeter is used in parallel to measure voltage.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.

Activity 10
Watt's Power, Energy, and Voltage

When James Watt was working to develop a practical steam engine, he needed a way to compare the effectiveness of different engines. The engines had to be evaluated in terms of the rate at which they could produce usable energy. He called that rate the *power* of the engine. He established a standard—*horsepower*—by measuring the rate at which horses could lift heavy rocks out of a well.

Today, energy is often measured in *joules*. Figure 10–1 shows common examples of energy use with which you are familiar. As you can see a joule is a rather small unit.

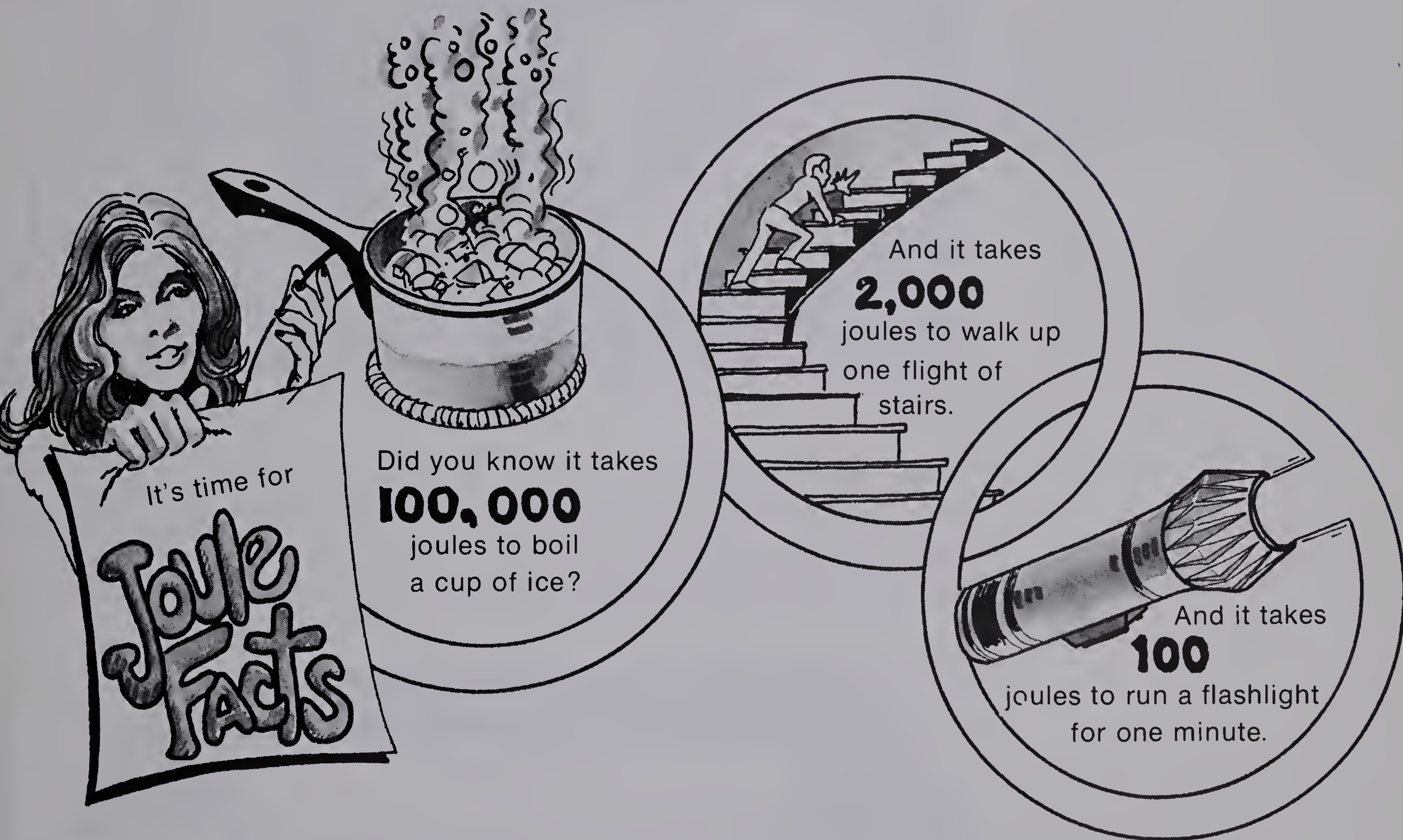


Figure 10–1

• 10–1. Which activity in Figure 10–1 needs the most energy?

10-1. Boiling a cup of ice.

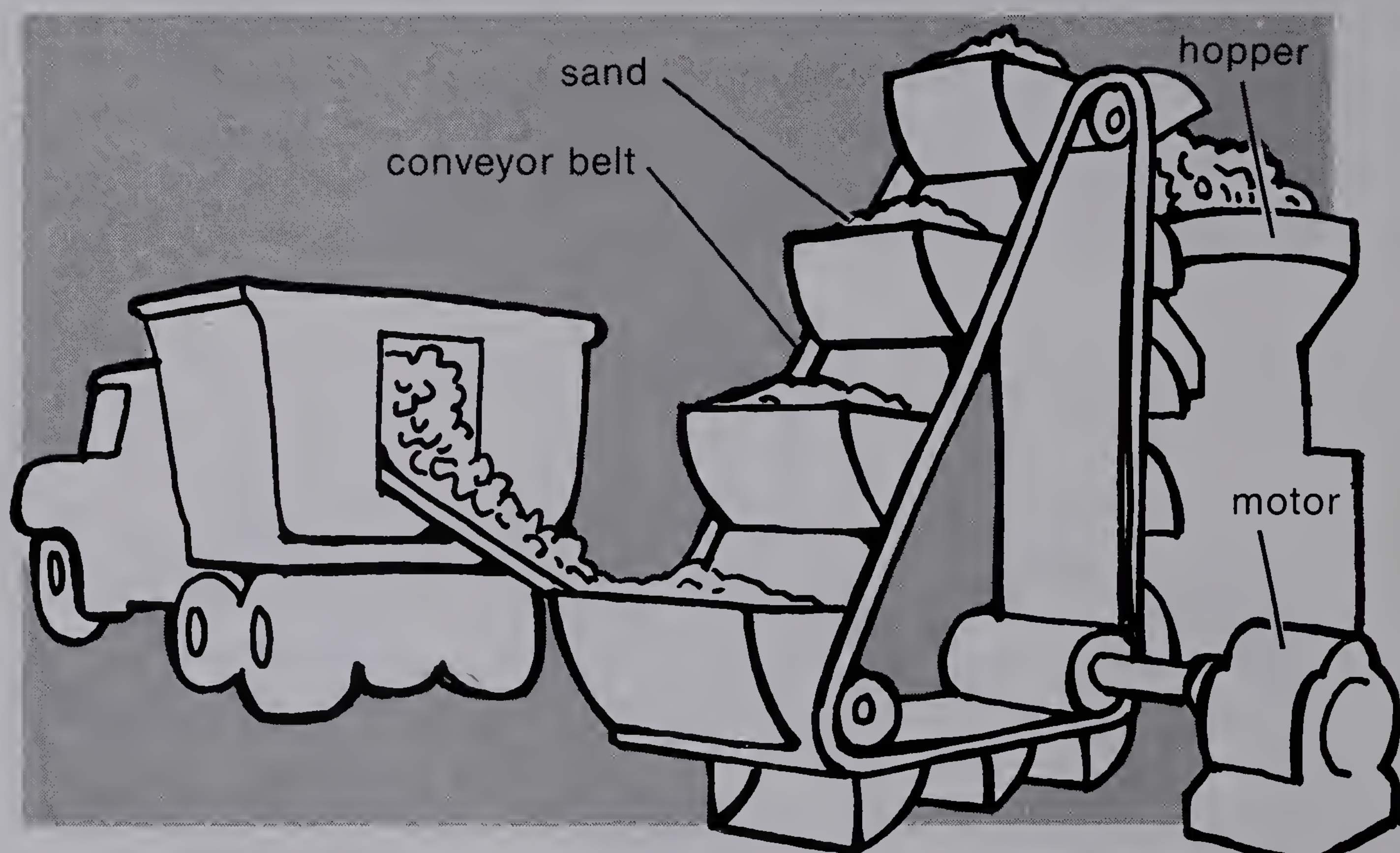
• 10–2. If 2000 joules are required to walk up one flight of stairs, what other factor determines how much power is needed?

10.2. The time it takes to walk up the steps.

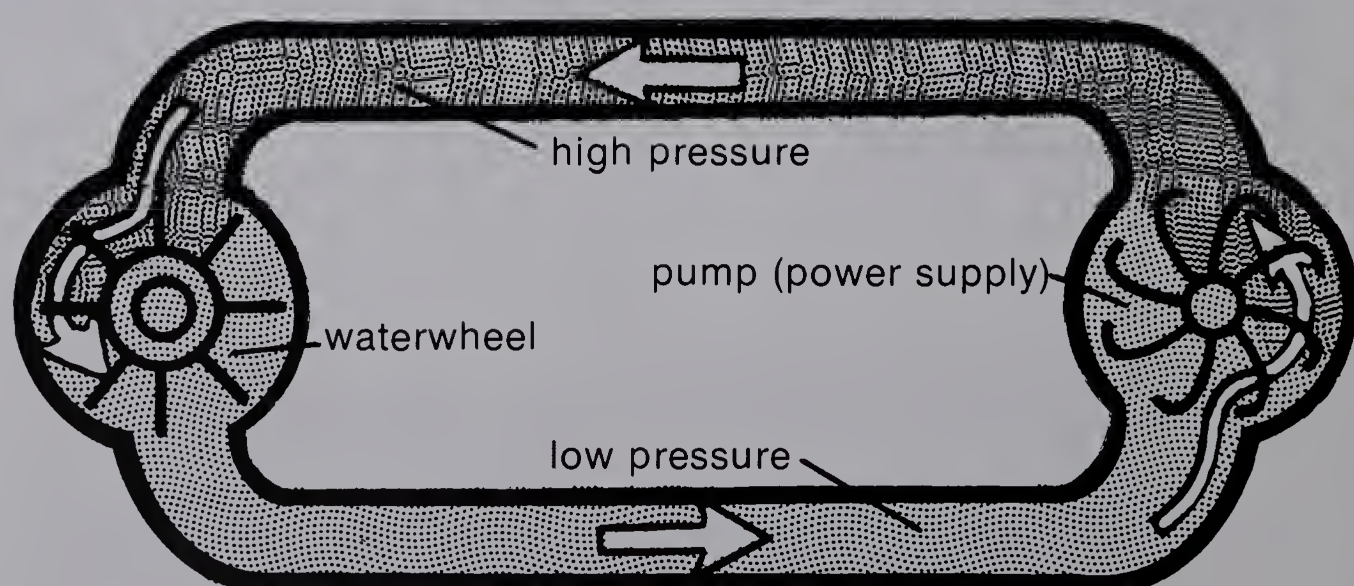
Power, the rate at which energy is used or produced, is measured in *joules per second,* or *watts*.

When an engineer wants to use an electric motor to do a job, he must make a decision about the size of the motor needed. The decision depends on the rate at which the motor must produce usuable energy. The bigger a motor is, the more electric power it uses, and the more mechanical power it produces.

Suppose the motor is to operate a belt that is lifting sand into a hopper. The power of the motor needed depends on how much sand is to be delivered per second and how high it must be raised.



You can think about this in terms of a water circuit. The motor in the electric circuit is like a waterwheel in a pipe. The waterwheel is turned by the water flowing past it. If you connect a waterwheel to the belt, you can use it instead of the motor to raise the sand.



Now suppose you wanted to lift more sand each second. Figure 10–2 shows two different ways you could do that.

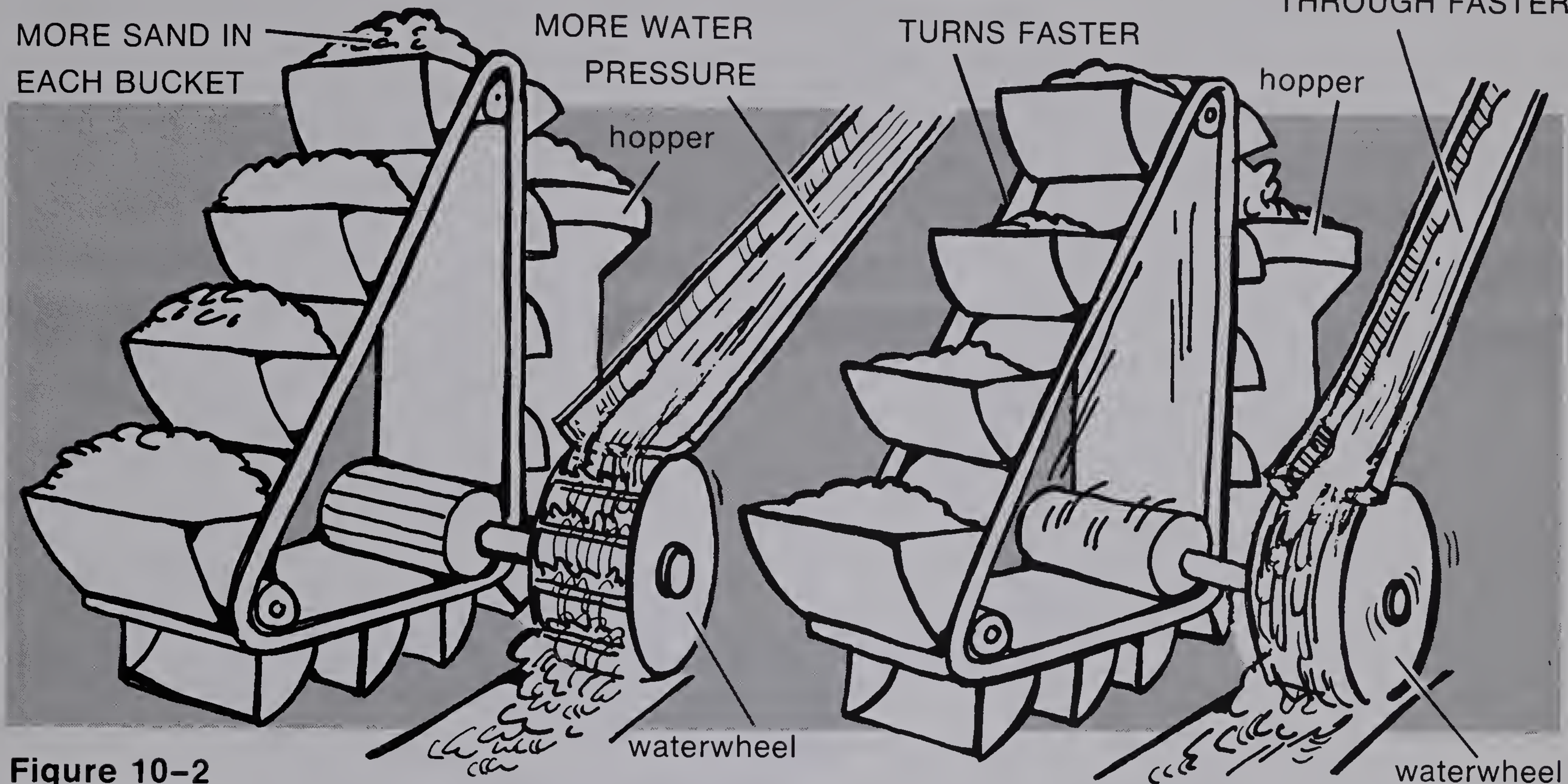


Figure 10–2

- 10–3. What two changes in the water supply shown in Figure 10–2 cause more sand to be lifted?

10-3. More water pressure (more water), so more sand can be put in each bucket. Water running faster, so conveyor belt moves faster.

The two changes in water supply shown in Figure 10–2 can also be related to voltage and current as suggested in Core Activity 2.

- 10–4. Is increasing the rate at which the water flows similar to an increase in electric current?

10-4. Yes.

- 10–5. Is increasing the pressure of the water similar to an increase in electric voltage (potential)?

10-5. Yes.

The electric power delivered to a motor or any other electric machine depends on both the current and the voltage (potential difference).

$$\text{current} \times \text{voltage (potential difference)} = \text{power}$$

If the current is given in amperes and the potential difference in volts, the power will be in joules/seconds or watts.

★ **10–6. If a light bulb uses 2 amperes at 120 volts, at what rate (in watts) is it using electrical energy?**

10-6. $P = VI$
$P = (120 \text{ volts})(2 \text{ amperes})$
$P = 240 \text{ watts}$

You have already learned that current (amperes) is a measure of how much charge flows past a point each second. The actual amount of energy a charge has depends on where it is in a circuit.

Think in terms of water. Water has a lot of energy when it is at the top of a mountain, but not at the bottom. When water flows down the mountain, it can give its energy to a turbine. In the same way, when an electric charge flows from a point of high potential in a circuit to a point of low potential, it can give its energy to a light bulb. (Figure 10–3).

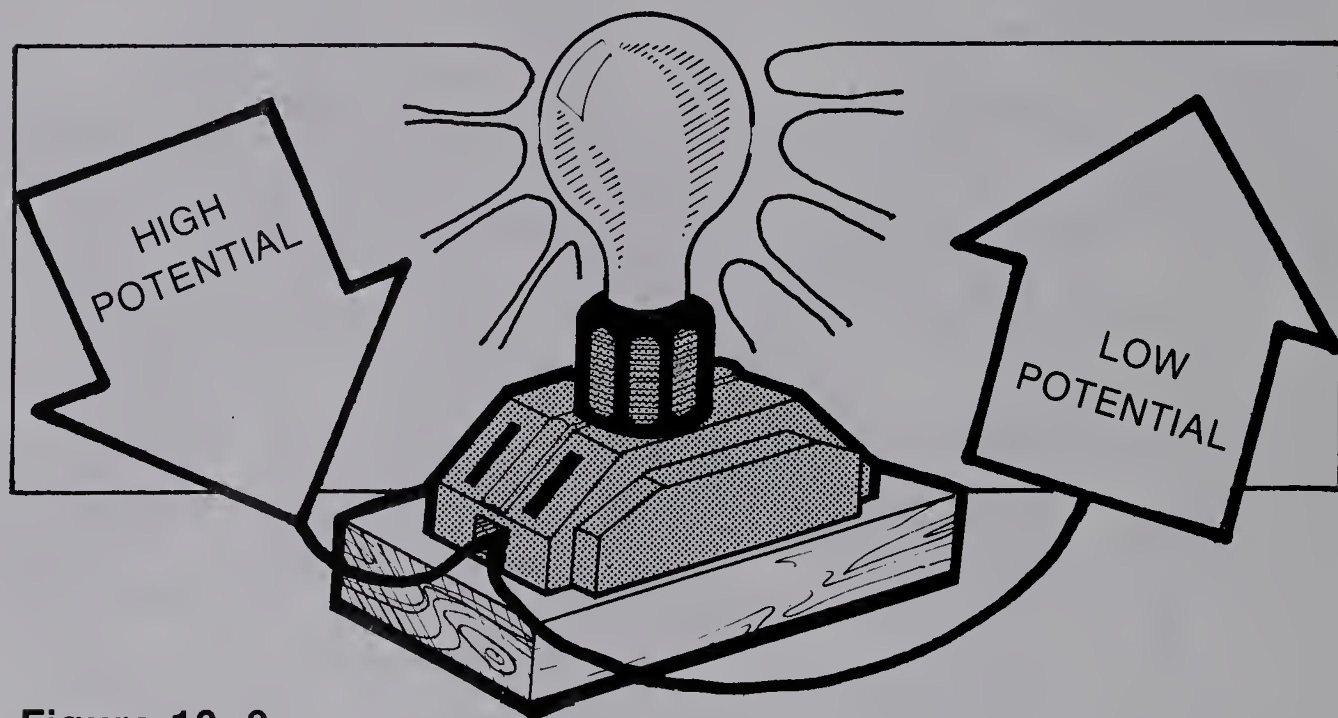


Figure 10–3

A battery or power supply gives energy to an electric charge. Each coulomb at the red (+) terminal of a 12-volt battery has twelve joules more energy than a coulomb at the black (−) terminal.

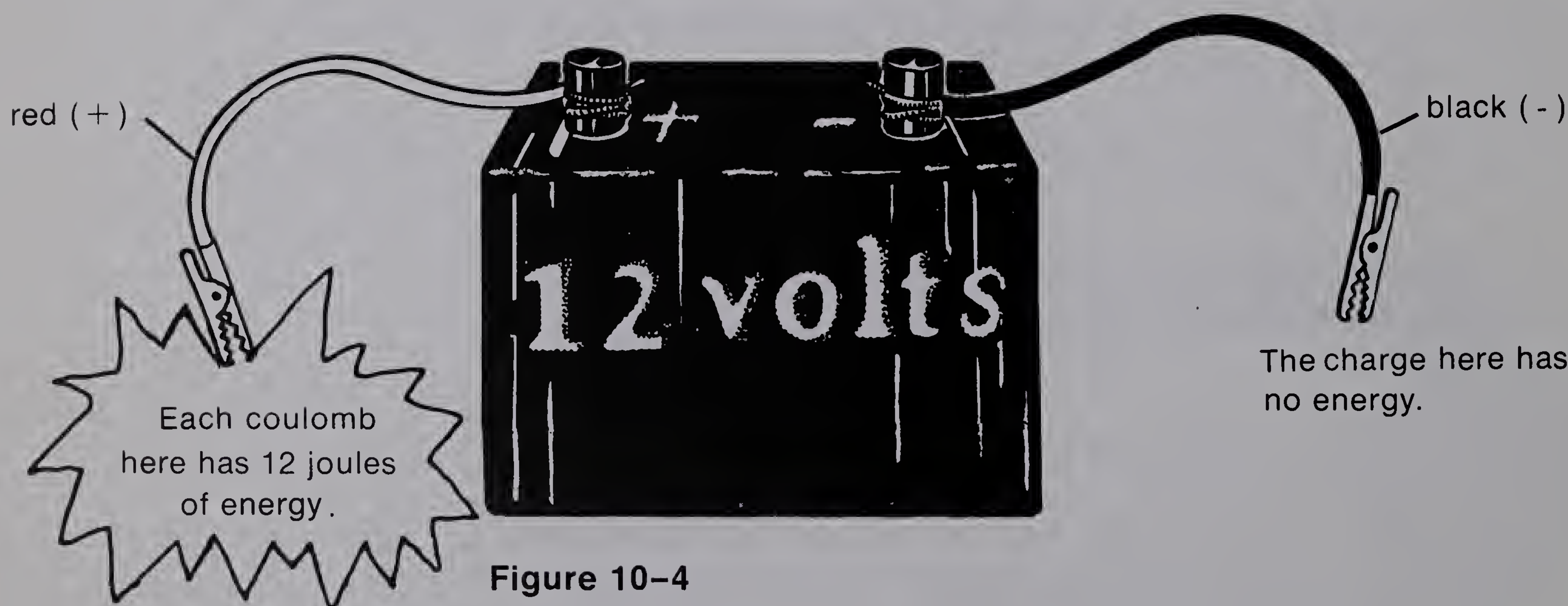


Figure 10–4

10-7. 24,000 joules (2000 coulombs X 12 volts)

★ **10–7. How much energy is stored in a battery that keeps 2000 coulombs at a potential of 12 volts?**

A voltmeter measures the difference between two potentials. For example, if the voltmeter is connected at one point where the potential is 60 volts and at another where it is 40 volts, the voltmeter will register 20 volts (60 volts − 40 volts = 20 volts).

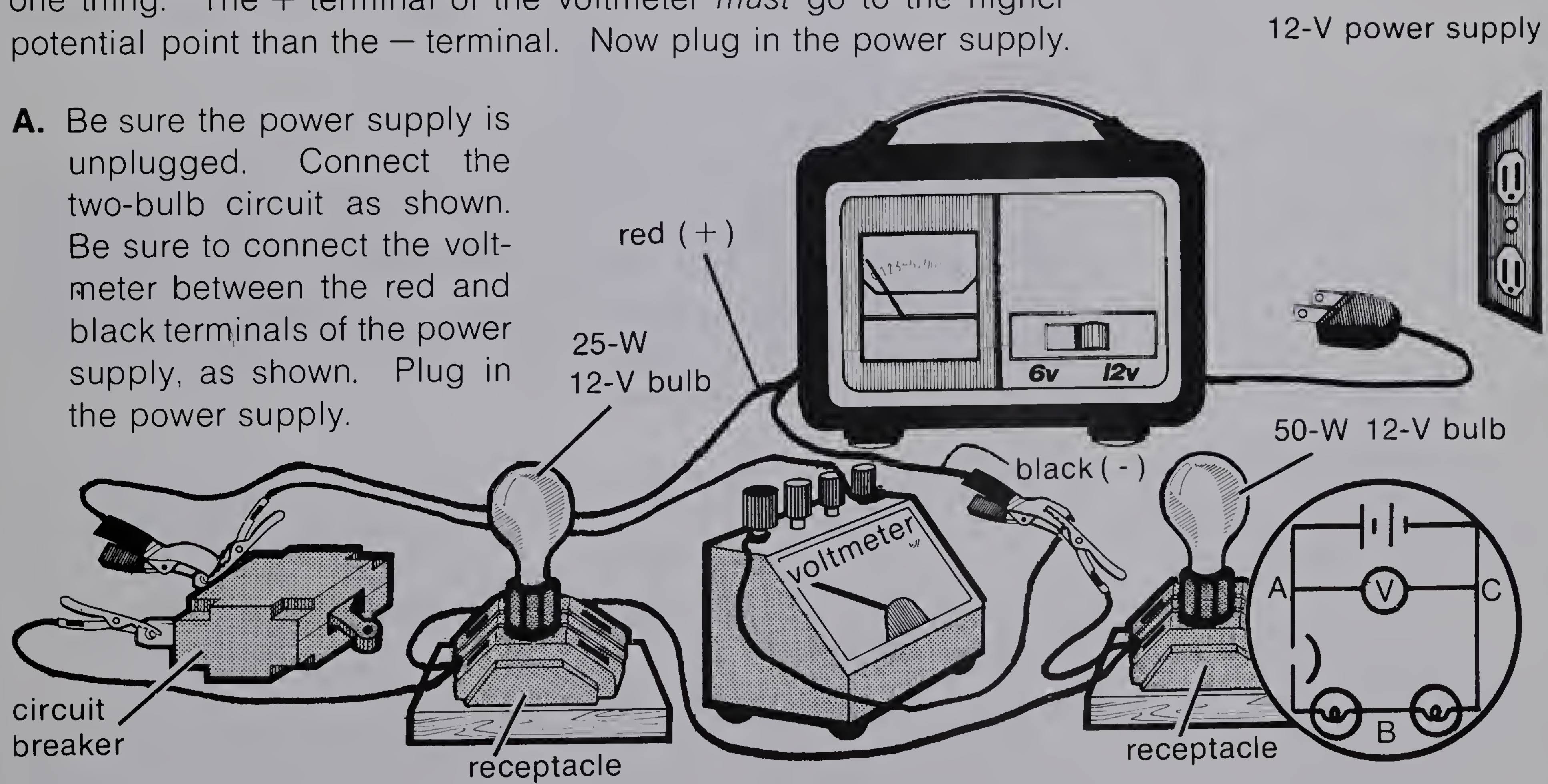
Use a voltmeter to find out how the energy of a electric charge changes as the charge goes through a two-bulb circuit. You will need the following:

power supply, 12-V, DC
2 bulb sockets
bulb, 25-W, 12-V
bulb, 50-W, 12-V
circuit breaker, 5-A
2 3-outlet receptacles
voltmeter, about 15-V, DC
2 20-cm lengths of insulated wire

CAUTION **Be sure your hands are dry when working with electricity.**

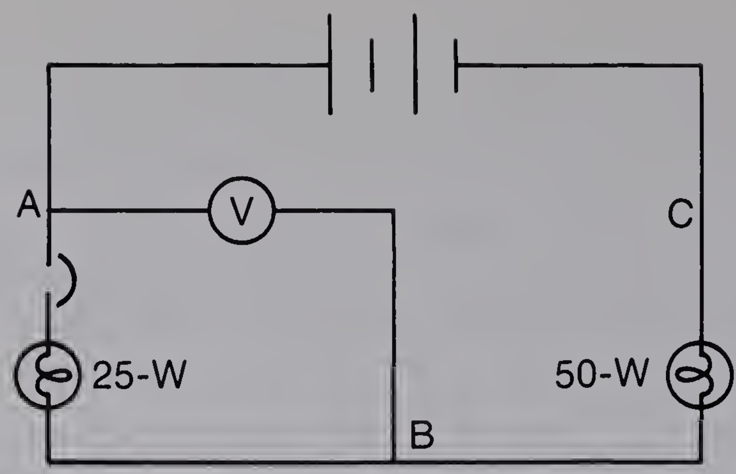
To measure a potential difference between any two points just connect the voltmeter leads to those points. You must watch out for one thing. The + terminal of the voltmeter *must* go to the higher potential point than the − terminal. Now plug in the power supply.

A. Be sure the power supply is unplugged. Connect the two-bulb circuit as shown. Be sure to connect the voltmeter between the red and black terminals of the power supply, as shown. Plug in the power supply.



• 10–8. What is the potential difference between Points A and C in the circuit?

10-8. Probably between 11 and 12 volts.



B. Unplug the power supply. Disconnect the voltmeter, and reconnect it to measure the potential difference between Points A and B. Note that you do not have to reconnect anything except the voltmeter.

10-9. Probably about 9 volts.

- 10–9. What is the potential difference between Points A and B?

10-10. About 9 joules.

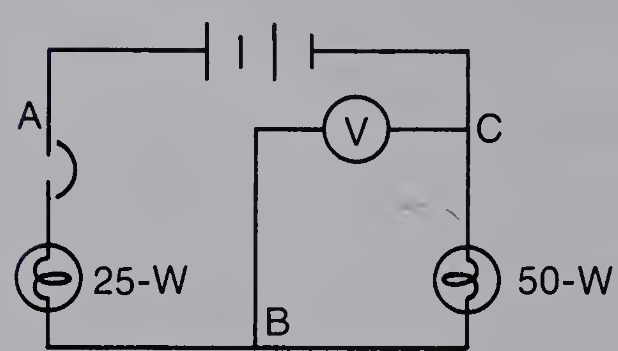
- 10–10. How much energy was lost by each coulomb of charge in passing through the 25-watt bulb?

10-11. About 3 joules.

- 10–11. How much energy did each coulomb have left after it went through the 25-watt light bulb?

10-12. About 3 volts.

- 10–12. From your answer to Question 10–11, what would you predict the potential difference to be between Points B and C in the circuit?



C. Now check out your prediction in Question 10–12. Measure the potential difference between Points B and C. Set up the voltmeter as shown.

10-13. Hopefully, yes.

- 10–13. Does your measurement agree with the prediction you made?

10-14. c

★ 10–14. When properly connected, there is very little current
a. in both an ammeter and a voltmeter.
b. in an ammeter only.
c. in a voltmeter only.

10-15. P = VI. When the voltage is about 9.0 volts, the power consumed is 9.0 X 1.75, or 15.75 watts. 15.75 watts.

- 10–15. Assume that 1.75 amperes flow through the two bulbs in the investigation you just completed. What was the actual power consumed by the 25-watt bulb? (Hint: What was the potential difference you measured across the bulb?)

Just why is it that voltage times current gives power? Recall that current (I) is the amount of electric charge (Q) that flows past a given point per unit of time (t).

$$I = \frac{Q}{t}$$

Potential difference (V) is the amount of energy (E) that each unit charge loses in going from one place to another.

$$V = \frac{E}{Q}$$

Multiplying V and I together gives you the following.

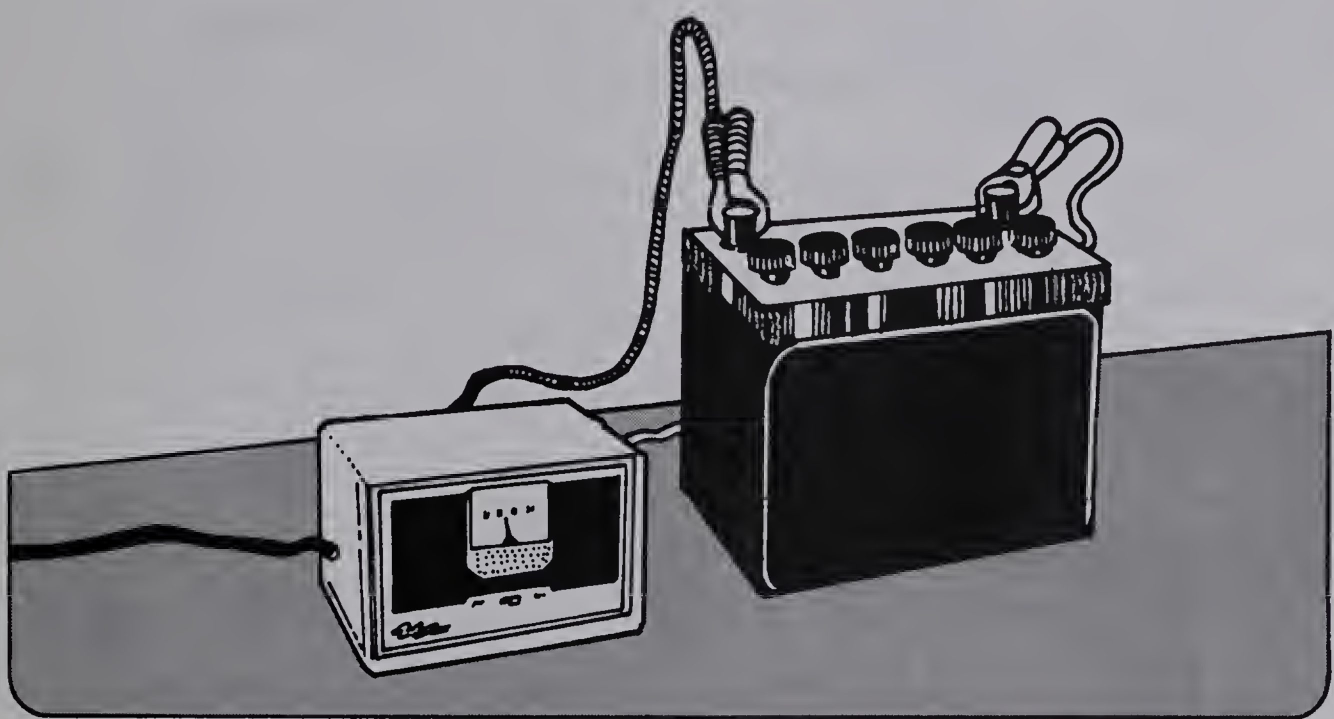
$$VI = \frac{E}{Q} \times \frac{Q}{t} = \frac{E}{t}$$

But power (P) is defined as amount of energy lost per unit of time.

$$P = \frac{E}{t}$$

Since both VI and P equal E/t, then VI = P.

Some systems gain electrical energy. A storage battery can be charged by forcing current through it. It stores the energy of the current to be used later. Now, you should be able to answer some questions about a storage battery.



- 10–16. A 12-volt storage battery is being charged with a 20-ampere current. What is the power in watts used in charging the battery?

- 10–17. If the charging (Question 10–16) continues for 10 minutes and no energy is lost in the process, how much energy is stored in the battery? (Hint: The energy will be measured in watts-seconds or joules.)

- 10–18. If the battery is then used to supply current at 1 ampere, how long will the energy that has just been added last?

10-16. $P = VI$
$P = (12 \text{ volts})(20 \text{ amperes})$
$P = 240 \text{ watts}$

10-17. $P = \frac{E}{t}$
$E = Pt$
$E = (240 \text{ watts}) \times (600 \text{ seconds})$
$E = 144{,}000 \text{ joules}$

10-18. $VI = \frac{E}{t}$
$t = \frac{E}{VI}$
$t = \frac{144{,}000 \text{ joules}}{(12 \text{ volts})(1 \text{ ampere})}$
$t = 12{,}000 \text{ seconds}$
$= 200 \text{ minutes}$
$= 3.3 \text{ hours}$

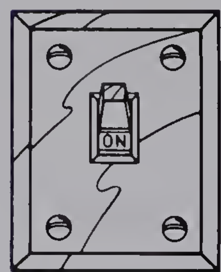
If a light bulb is rated at 110 volts, 60 watts, it means that the bulb is designed to work on a 110-volt circuit. In that circuit, it will use electrical energy at the rate of 60 watts, or 60 joules of energy every second.

10-19. It would burn out or explode.

• 10–19. What do you think would happen if that bulb were connected to a 220-volt circuit?

ACTIVITY EMPHASIS: Resistance is the ratio of potential difference (voltage) to current: R = V ÷ I.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.



Activity 11
Resisting Current

Each appliance in a household circuit will use its own characteristic amount of current. In a core activity you were responsible for knowing how to use voltage and power ratings to determine the current. If you can't remember how to determine current, look at page 34.

11-1. $\frac{25 \text{ watts}}{12 \text{ volts}} = 2.08$ amperes

• 11–1. How much current will be drawn in normal use by a bulb rated at 12 volts, 25 watts?

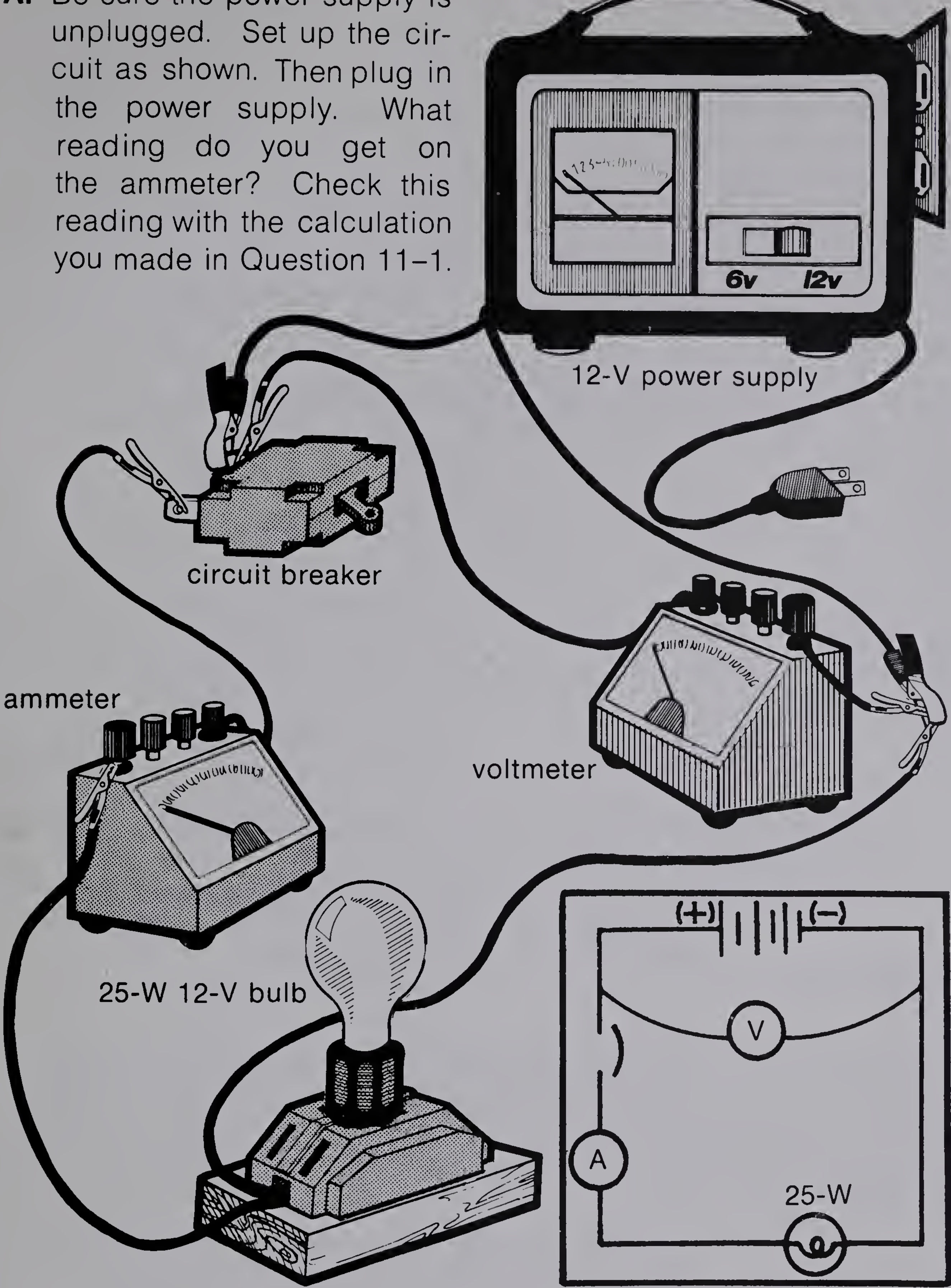
In this activity, you will try to measure the current and compare it to the value you calculated. You will need the following materials:

power supply, 12-V DC
2 20-cm lengths of insulated wire (leads)
ammeter, about 5-A
voltmeter, 15-V DC
2 bulb sockets
circuit breaker, about 5-A
bulb, 25-W, 12-V
bulb, 50-W, 12-V
3-outlet receptacle

CAUTION **Do not plug in the power supply until after you have made all the electrical connections.**

Be sure your hands are dry when working with electricity.

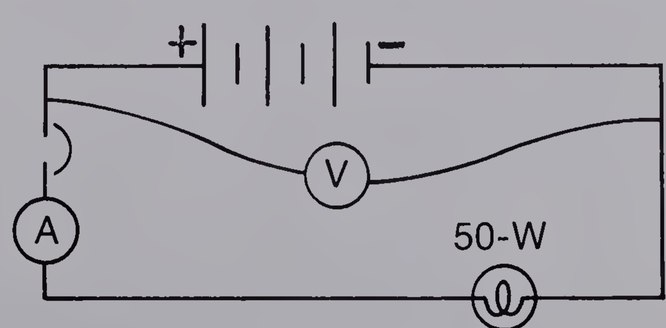
A. Be sure the power supply is unplugged. Set up the circuit as shown. Then plug in the power supply. What reading do you get on the ammeter? Check this reading with the calculation you made in Question 11–1.



• 11–2. How close does your measurement agree with the calculated value?

11-2. Answers will vary, but the values should be similar, about 2 amperes. Properties of the power supply are probably responsible for the voltage not being exactly 12 volts.

B. Be sure the power supply is unplugged. Replace the 25-watt bulb with a 50-watt bulb. Plug in the power supply.



• 11–3. How much current does the 50-watt bulb draw?

11-3. 4 amperes

Georg Ohm

Clearly, there is something different about the 50-watt bulb. In 1827, a German teacher named Georg Ohm published the results of some investigations into the factors that determine the amount of current in a circuit. He found that by using different numbers of batteries to vary the potential difference, he could produce different amounts of current in a wire. An experiment of this kind might give data like those shown in Figure 11–1. If you need help reading the graph look at *Resource Unit 2.*

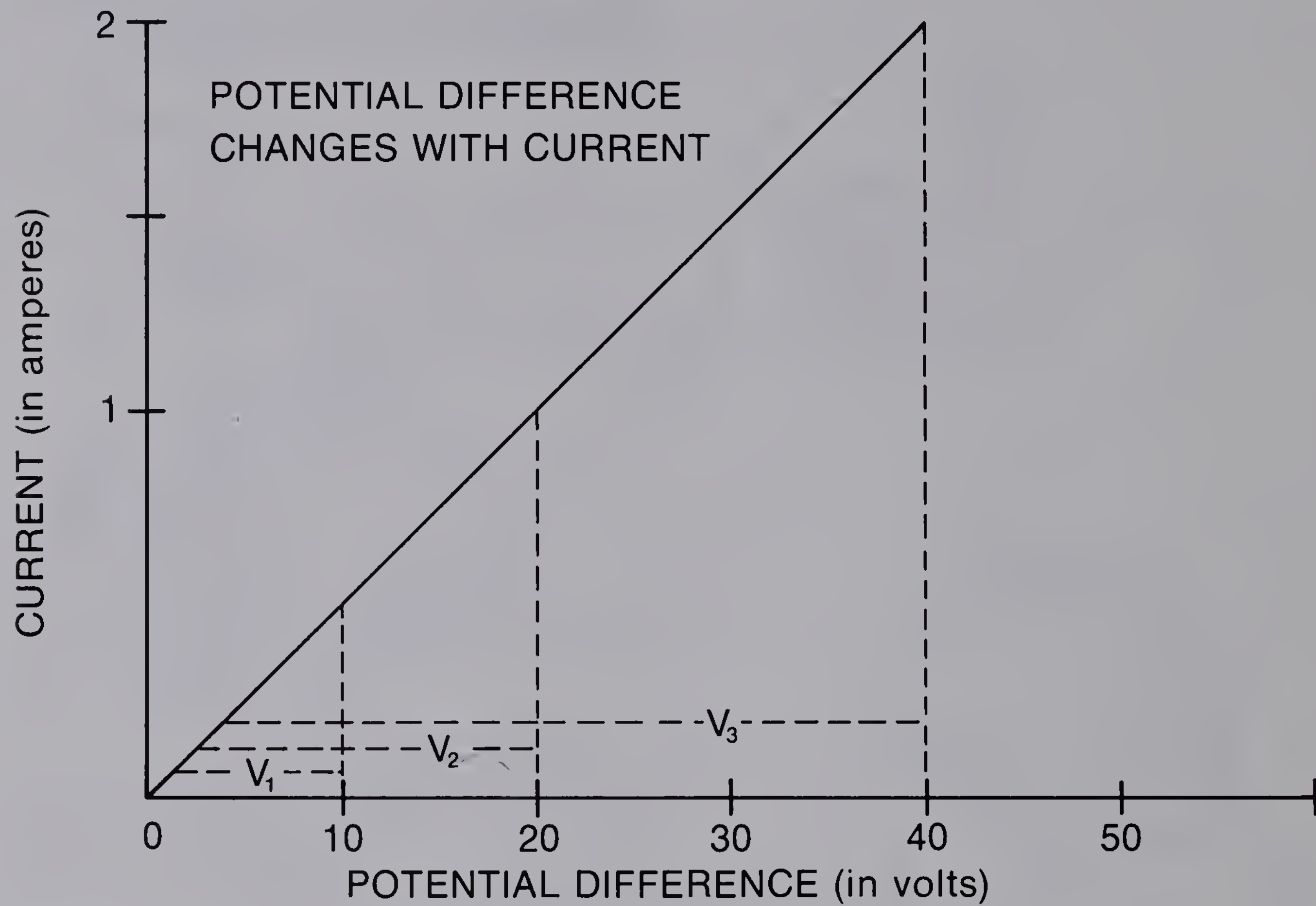


Figure 11–1

Have *Resource Unit 2* available to aid students in reading the graph.

In Figure 11–1, if there were no errors of measurement, all points would fall on a straight line. The line passes through the origin, because when the voltage equals zero, no current can flow. Since this line is a straight line, I (current) is also directly proportional to V (volts).

$$\frac{V_1}{I_1} = \frac{V_2}{I_2} = \frac{V_3}{I_3} = \frac{V_4}{I_4} \text{ etc.}$$

In other words, V/I is a constant. This rule is generally true for any metal wire that is kept at a constant temperature and it is known as *Ohm's Law.*

11-4. Since the volts/current ratio is constant, expect three times the current on 4.5 amperes.

- 11–4. The data given in Figure 11–1 show that 30 volts of potential difference produce 1.5 amperes of current. Suppose you took the same conductor and applied three times as much potential difference (90 volts) to it. How much current would you expect to get?

The ratio V/I is a characteristic of a given conductor under a particular set of conditions. It is called the *resistance* of the conductor and is measured in *ohms*. When the potential difference is in volts and the current is in amperes, the resistance is in ohms.

POTENTIAL DIFFERENCE CHANGES WITH CURRENT

POTENTIAL DIFFERENCE (in volts)	**CURRENT** (in amperes)
10	0.5
20	1.0
30	1.5
40	2.0
50	2.5
60	3.0

For example, take the wire used in making the graph in Figure 11–1.

$$\text{resistance} = \frac{\text{potential difference (voltage)}}{\text{current}}$$

$$R = \frac{V}{I}$$

$$R = \frac{30 \text{ volts}}{1.5 \text{ amperes}}$$

$$R = 20 \text{ ohms}$$

★ **11–5. Define resistance in terms of a ratio.**

• 11–6. Does a 50-watt bulb have more or less resistance than a 25-watt bulb? (Use the current ratings from Questions 11–1 and 11–3.)

★ **11–7. What is the resistance of a light bulb operating at its rated value of 120 volts, 60 watts? (Hint: First find the current.)**

• 11–8. Another resistor is carrying 0.5 ampere when one end of it is at a potential of 260 volts and the other end is at 220 volts. What is the resistance?

11-5. Resistance is the potential difference (voltage) to current.

11-6. Less, since $R = \frac{V}{I}$

For the 50-watt bulb

$$R = \frac{12 \text{ volts}}{4 \text{ amperes}} = 3 \text{ ohms.}$$

For the 25-watt bulb

$$R = \frac{12 \text{ volts}}{2 \text{ amperes}} = 6 \text{ ohms.}$$

11-7. 240 ohms

$$I = \frac{\text{watts}}{\text{volts}} = \frac{60 \text{ watts}}{120 \text{ volts}}$$

$$= 0.5 \text{ amperes}$$

$$R = \frac{V}{I} = \frac{120 \text{ volts}}{0.5 \text{ amperes}}$$

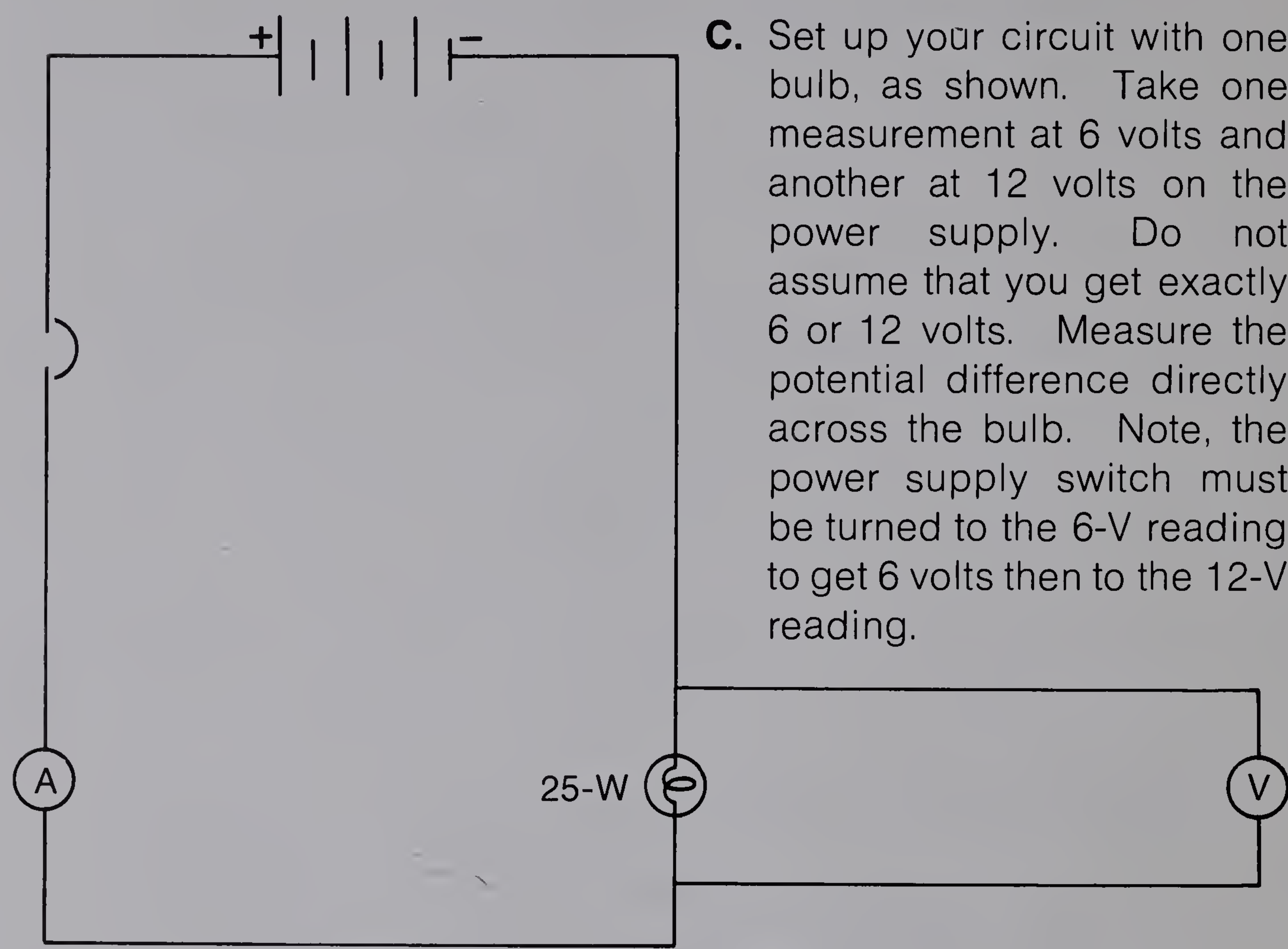
$$= 240 \text{ ohms}$$

11-8. $R = \frac{V}{I} = \frac{40 \text{ volts}}{0.5 \text{ amperes}}$

$$= 80 \text{ ohms}$$

Resistance may change when conditions change. In Step C you will measure the resistance of the 25-watt bulb with two different values of potential difference. In each case, you must measure potential difference and current. Then you must calculate resistance.

C. Set up your circuit with one bulb, as shown. Take one measurement at 6 volts and another at 12 volts on the power supply. Do not assume that you get exactly 6 or 12 volts. Measure the potential difference directly across the bulb. Note, the power supply switch must be turned to the 6-V reading to get 6 volts then to the 12-V reading.



RESISTANCE AND POTENTIAL DIFFERENCE

BRIGHTNESS OF BULB	POTENTIAL DIFFERENCE (in volts)	CURRENT (in amperes)	RESISTANCE (in ohms)
(?)	(?)	(?)	(?)
(?)	(?)	(?)	(?)

Figure 11–2

11-9. SAMPLE DATA

	VOLTS	AMPERES	OHMS
Dim	6	1.4	4.3
Bright	12	2.0	6.0

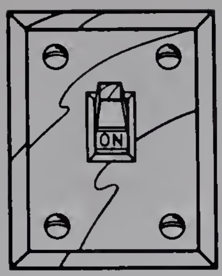
- 11–9. Fill in the values in a table like that in Figure 11–2, and calculate the resistances.

11-10. It increases.

- 11–10. The bulb gets bright as it gets hotter. What happens to the resistance of a bulb as its temperature increases?

11-11. The temperature must be kept constant.

★ **11–11. What condition is stated in Ohm's Law for V/I to stay constant?**



Activity 12
Two of a Kind

ACTIVITY EMPHASIS: Direct current always "moves" in one direction and becomes steady with time. Alternating current changes direction and potential (voltage). Alternating current is convenient to use because its potential is easier to alter for transport.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.

You can get electricity from either a flashlight battery or a wall outlet. But these are two different kinds of electricity—direct current (DC) and alternating current (AC).

When the switch of a flashlight is turned on, the current increases very quickly. Figure 12–1 shows what happens in the first two-millionths of a second.

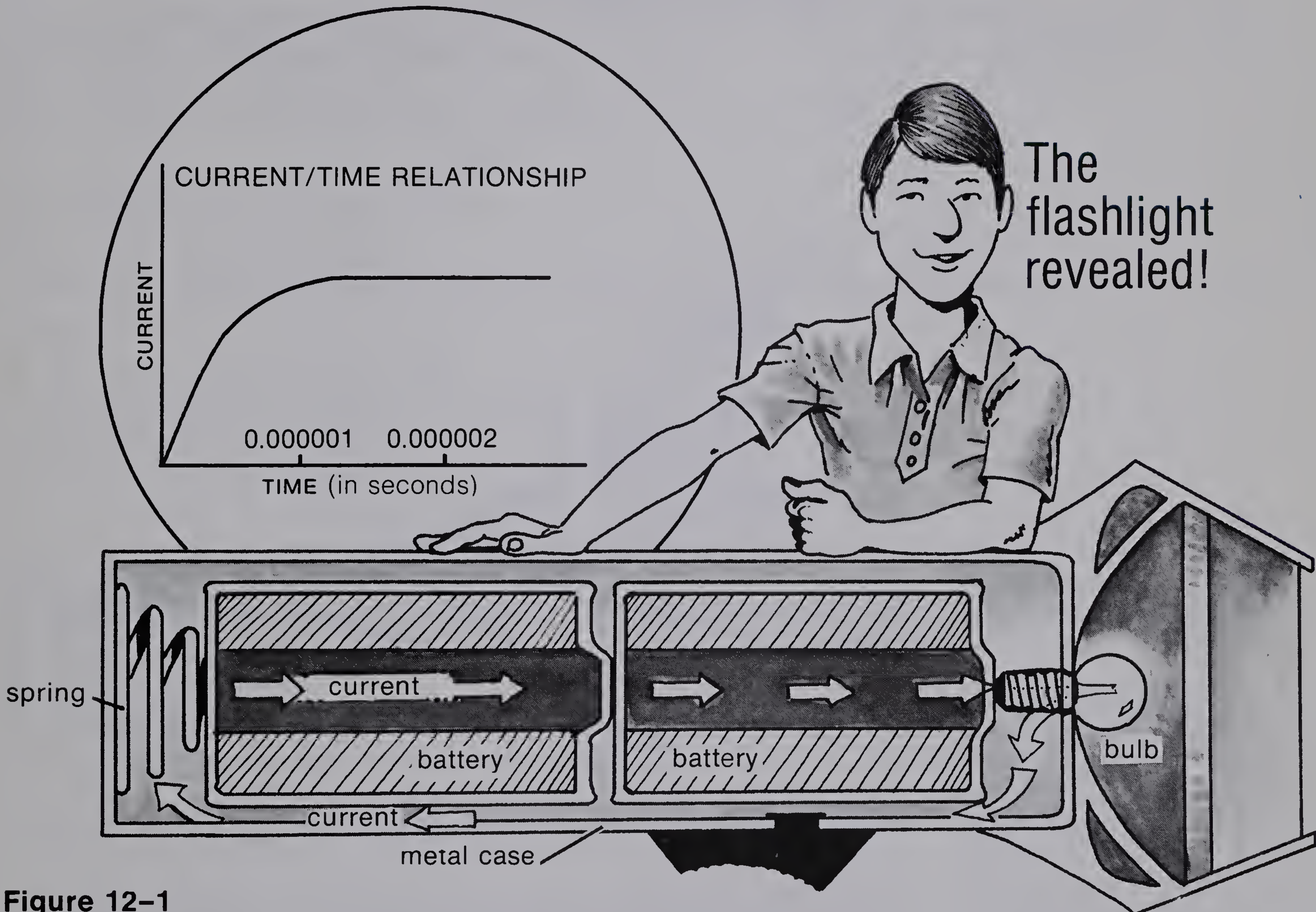


Figure 12–1

- 12–1. Does the current continue to increase with time or does it become steady?

- 12–2. Identify the conducting path for the current in a flashlight, starting at the positive (center) terminal of the battery nearer the bulb (Figure 12–1).

12-1. Becomes steady.

12-2. Current goes out the center terminal of that battery into the bulb. From the bulb it goes to the base of the other battery via the metal case and spring.

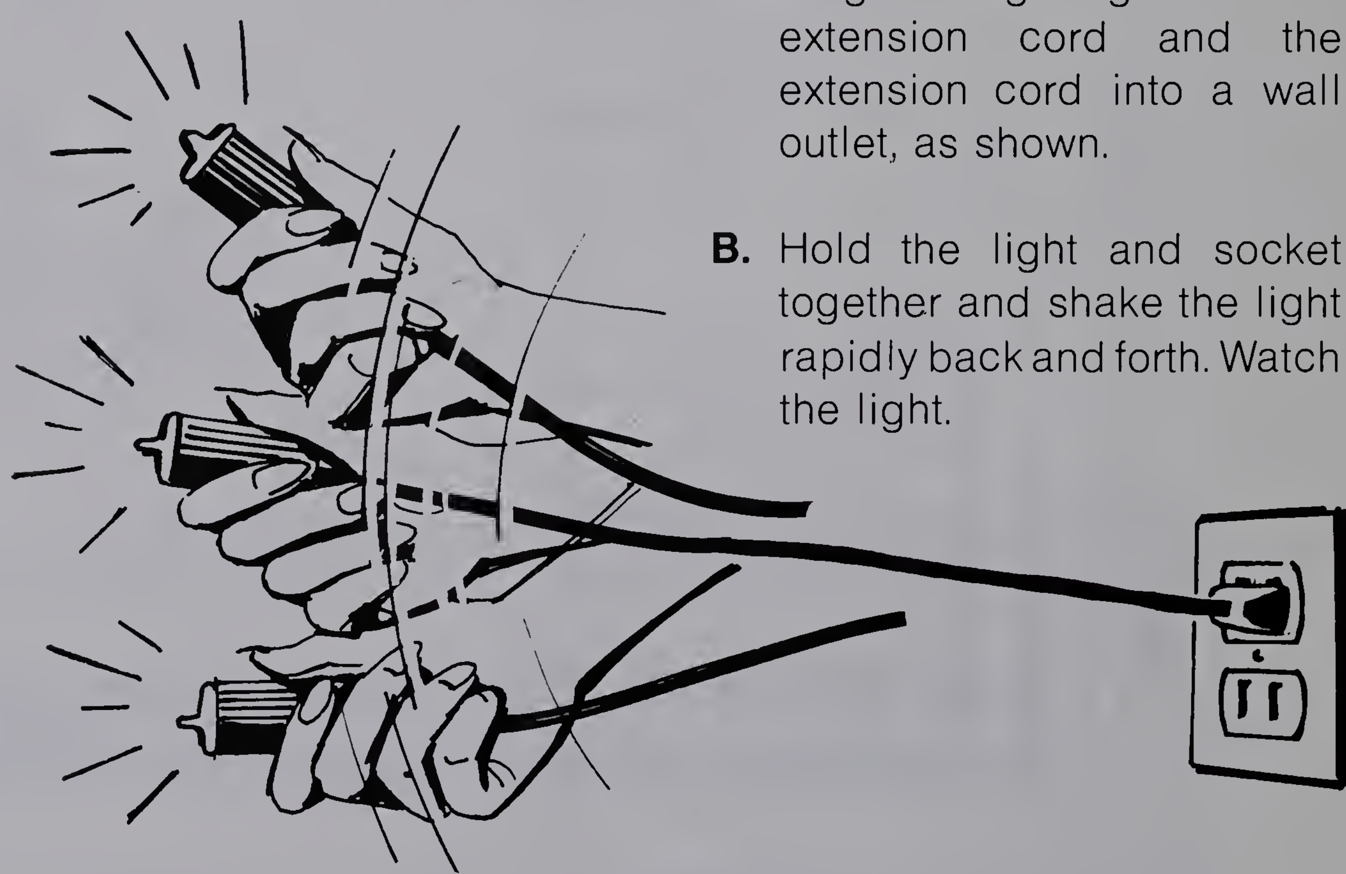
Because the current in the flashlight is always in the same direction, it is called *direct current* (DC). Alternating current (AC) is the kind used in all home lighting except for a few very old systems.

The following demonstration will throw some light on the difference between the two kinds of current. You will need the following materials:

extension cord
neon night-light

CAUTION **Do not swing the night-light by the cord.**

Be sure your hands are dry when this equipment is plugged in.



A. Plug the night-light into the extension cord and the extension cord into a wall outlet, as shown.

B. Hold the light and socket together and shake the light rapidly back and forth. Watch the light.

- 12–3. Describe how the light behaves.

The light is flashing on and off because the current in it is intermittent. The current goes on and off because the potential difference (voltage) at the wall outlet increases and decreases. When you move the light back and forth, you are now able to see the light flash.

- 12–4. How would the neon bulb act if it were connected to a DC potential?

12-3. It should be seen as a set of separate flashes.

The nerve endings in the retina of the eye have persistence: that is they behave as if light falls on them when light is off for a fraction of a second. By moving the light back and forth, the light image moves back and forth across different nerve endings in the retina. The nerves only respond when the light is on. The other nerves in the path do not respond because no light struck them.

12-4. It would glow steadily if the voltage is great enough.

Consider what is happening at the wall socket. One of its terminals is grounded and remains steady at ground potential, or zero volts. The potential at the other terminal is varying, as shown in Figure 12–2. If you're not sure you know how to interpret this graph, read *Resource Unit 2*.

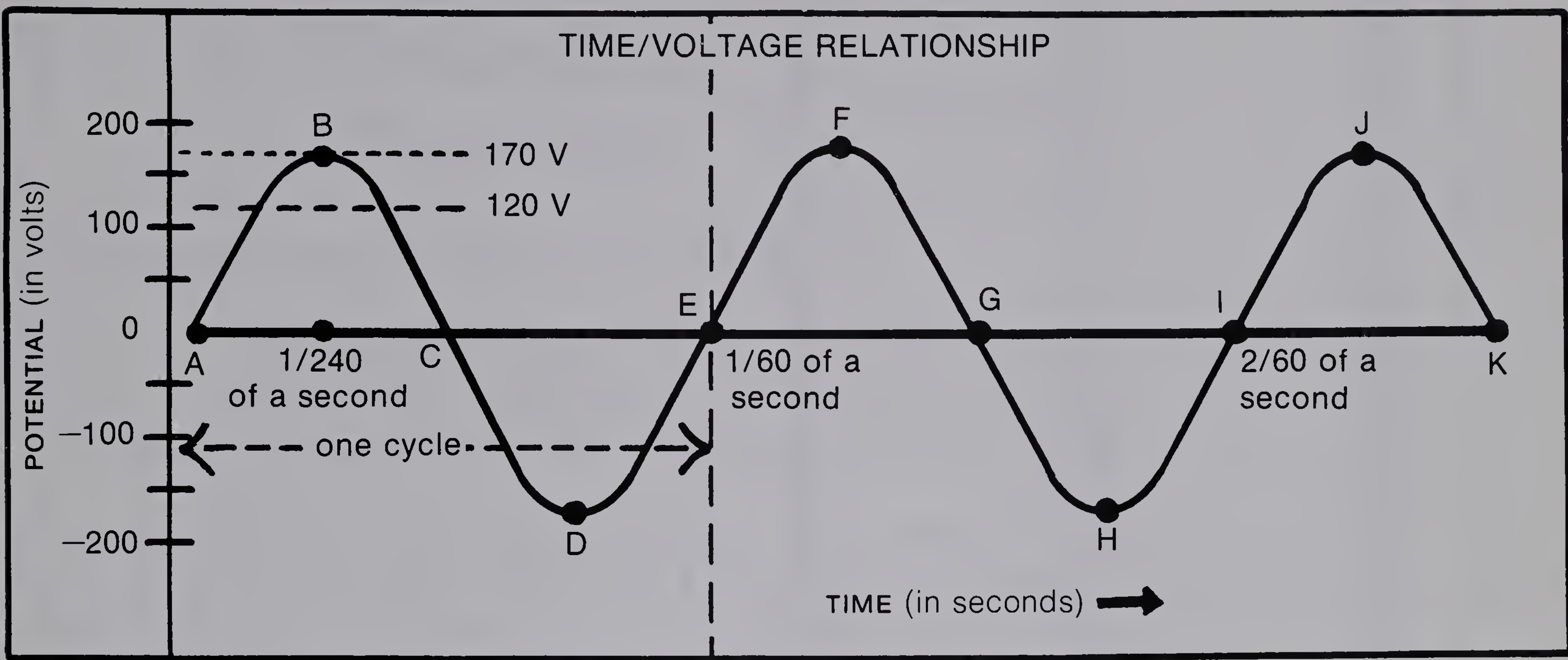


Figure 12–2

An AC potential goes from zero to maximum and then drops to zero again. Then it reverses—becomes negative—and reaches a maximum negative value (minimum). One complete cycle is from Point A to Point E. Then the pattern repeats over and over again.

★ **12–5. Use letters to identify at which moments of time on the graph the potential is maximum positive and minimum negative.**

12-5. Maximum positive: B, F, J. Maximum negative: D, H.

• 12–6. It takes about 60 volts to light the neon lamp. About how long after Point A does the lamp go on?

12-6. About $\frac{1}{1000}$ second.

• 12–7. How long does it take the potential to make one full cycle?

12-7. $\frac{1}{60}$ second

• 12–8. In Figure 12–2, how many cycles are completed in one second?

12-8. 60 cycles

The number of cycles completed in one second is called the *frequency*. Frequency is expressed in cycles per second, or *hertz* (Hz). In the United States, most of the AC has a frequency of 60 Hz. That means there are 60 cycles per second. A few places in the United States and much of Europe use frequencies of 50 Hz.

Figure 12–2 shows that the so-called 120-volts AC potential is actually changing constantly. A steady DC potential of 120 volts will cause a light bulb to burn just as bright. It turns out that the effective value of either AC potential or AC current is about 7/10 of its maximum value. Thus, the potential shown in Figure 12–2 has a maximum positive value of 170 volts and a maximum negative value of 170 volts. Its effective value—120 volts AC in this case—is always positive and can be figured from either the maximum positive or the maximum negative values.

12-9. 20 amperes

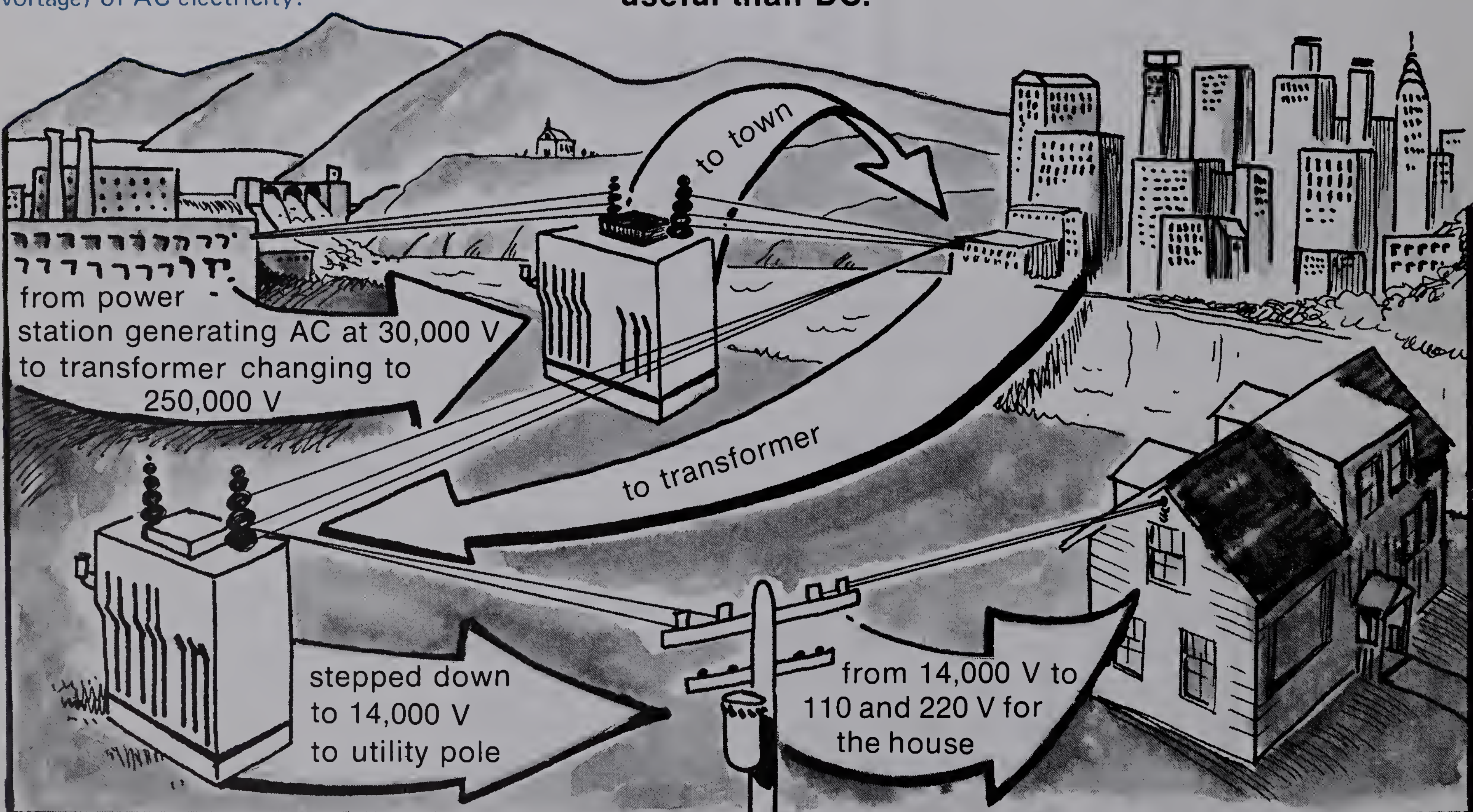
• 12–9. What is the maximum current in an electric heater that uses 14 amperes AC?

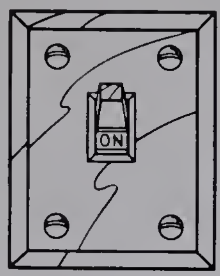
AC is much more convenient than DC because it is easier to change the potential of AC. This is done with very little loss of energy by a device called a *transformer*. Being able to change the potential allows transmission of electrical energy over long distances.

At 250,000 volts, it is possible to send lots of power with very little current in the lines. Since the current is small, the wires can be of reasonable thickness and yet have very little energy lost in them. Large currents needed in a home are in low voltage circuits only a short distance from a utility-pole transformer.

12-10. It can change potential (voltage) of AC electricity.

★ **12–10. Explain why using a transformer makes AC more useful than DC.**





Activity 13 Excursion Planning

Replacing a Plug
Activity 14 Page 64

If you have an appliance that won't work because of a broken plug or a frayed wire near the plug, you can fix it. This activity will show you how.

Small Heating Appliances
Activity 15 Page 69

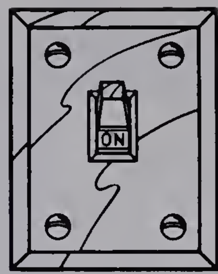
Ever wondered what in electric heaters converts electricity to heat? Or how the electric iron or toaster "knows" when to turn off? Those are interesting questions. You'll find the answers in this activity.

Your Home Circuits
Activity 16 Page 72

Do you know where the fuse box or circuit-breaker panel is in your home? Do you know what outlet goes with what fuse? In this excursion you learn how to quickly tell what circuits are affected when a fuse blows or a circuit breaker trips or kicks out.

ACTIVITY EMPHASIS: The replacement of a broken or frayed plug is accomplished by connecting the hot, neutral, and ground wires to the proper screws in a new plug.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.
See also Advance Preparation, p. TM 5.



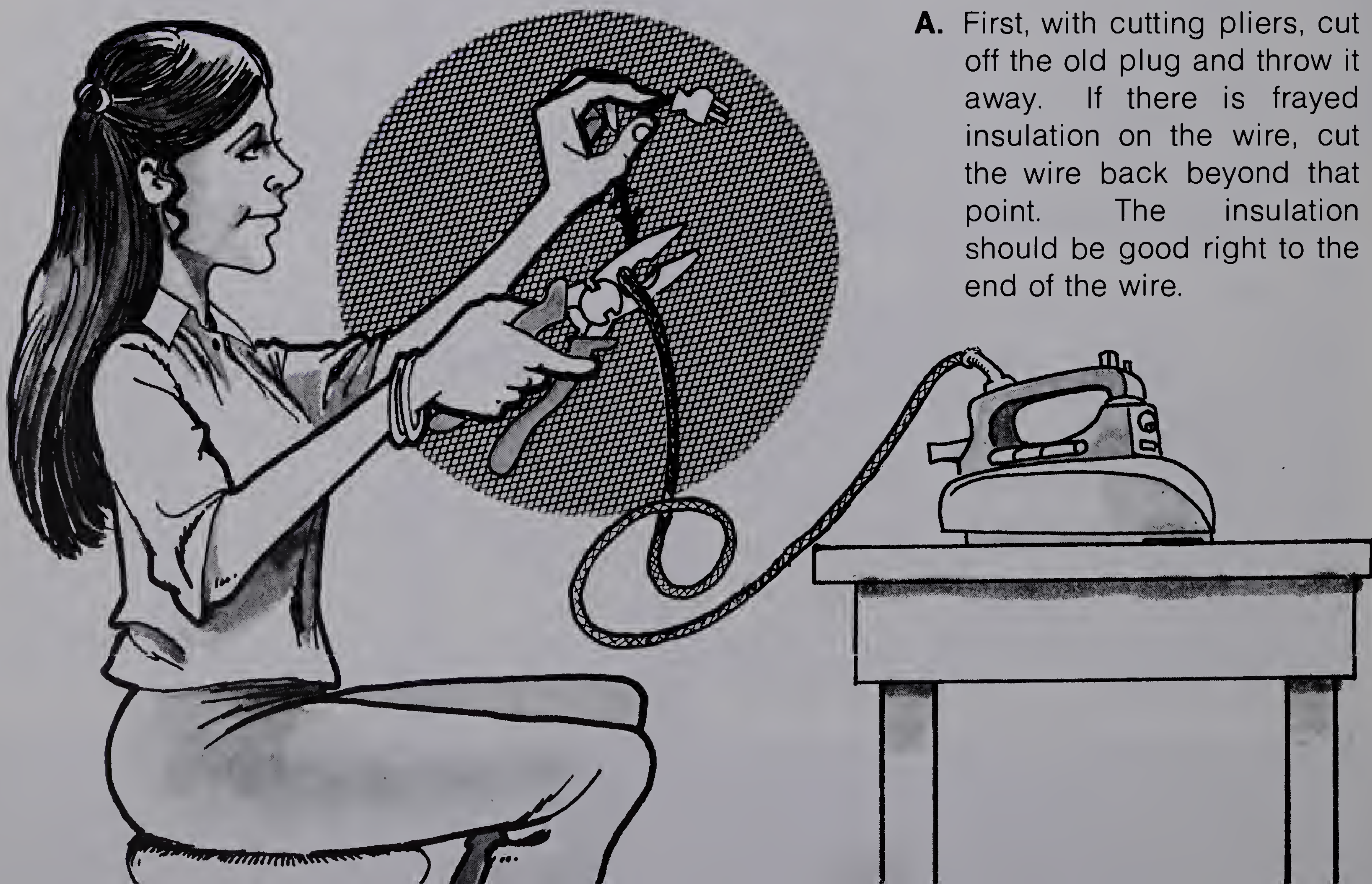
Activity 14
Replacing a Plug

Suppose you plug an appliance into an outlet and it doesn't work. The trouble may be that you have a faulty plug. The prongs may be bent. Or in a molded plug, wires may be disconnected. You can repair the trouble by replacing the plug. Just how is a plug repaired? To find out, you will need the following materials:

lamp or other appliance needing a plug replacement
plug (same type as that to be replaced)
cutting pliers
knife
screwdriver
pliers

CAUTION **Be sure your hands are dry when working with electricity.**

A. First, with cutting pliers, cut off the old plug and throw it away. If there is frayed insulation on the wire, cut the wire back beyond that point. The insulation should be good right to the end of the wire.



What you do next depends on what kind of plug and wire you have. Figure 14–1 describes different kinds of plugs and wires. It also tells you which activity steps need to be followed to repair them.

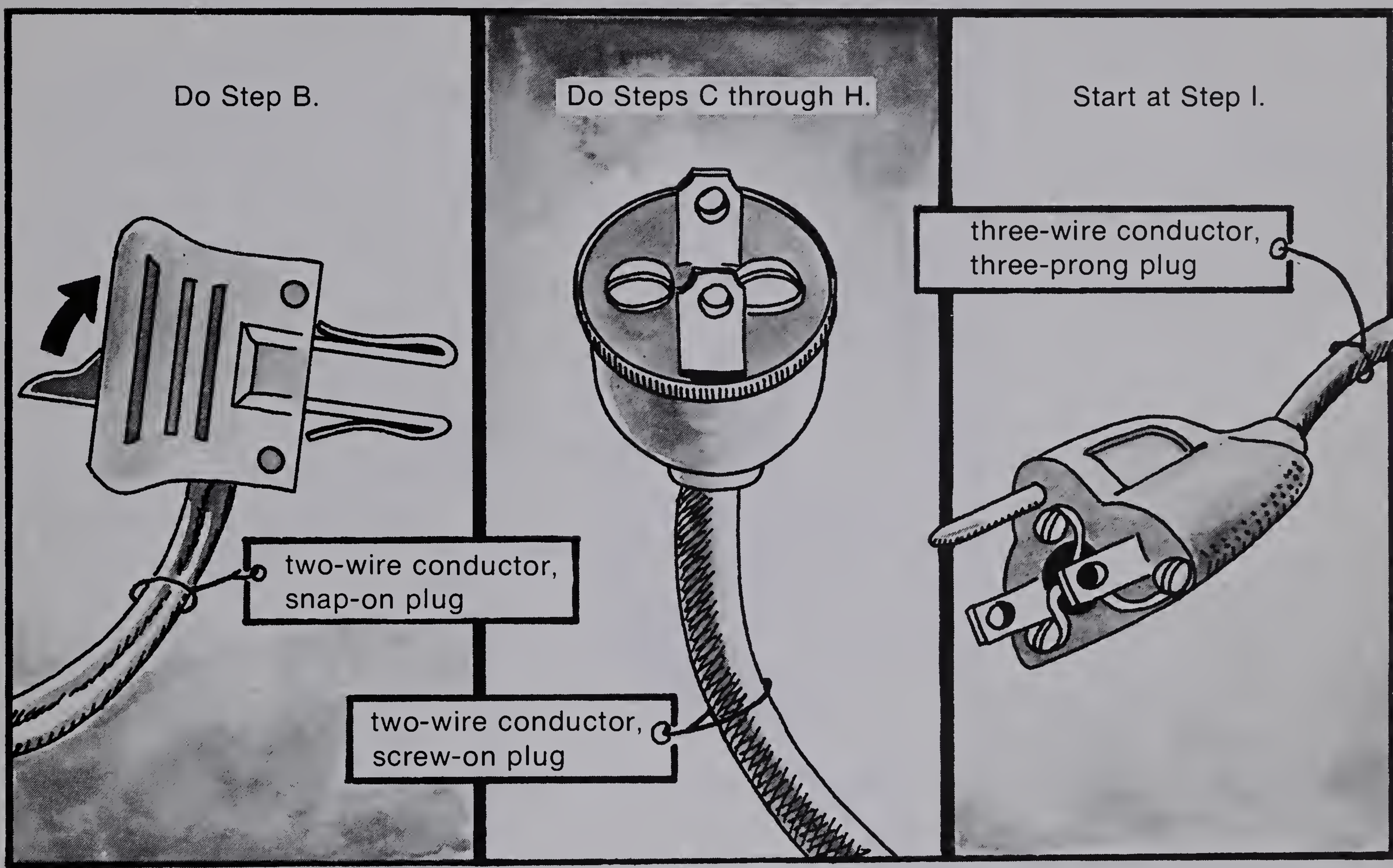
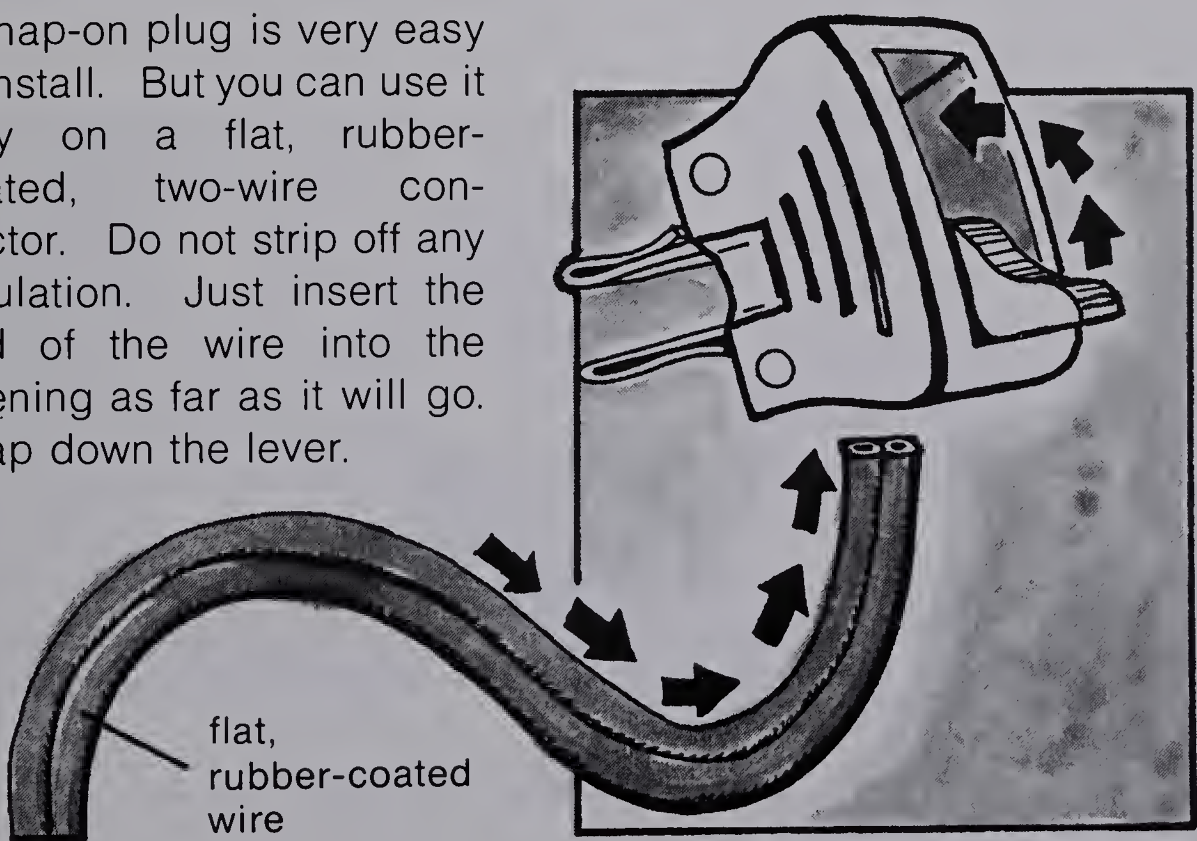
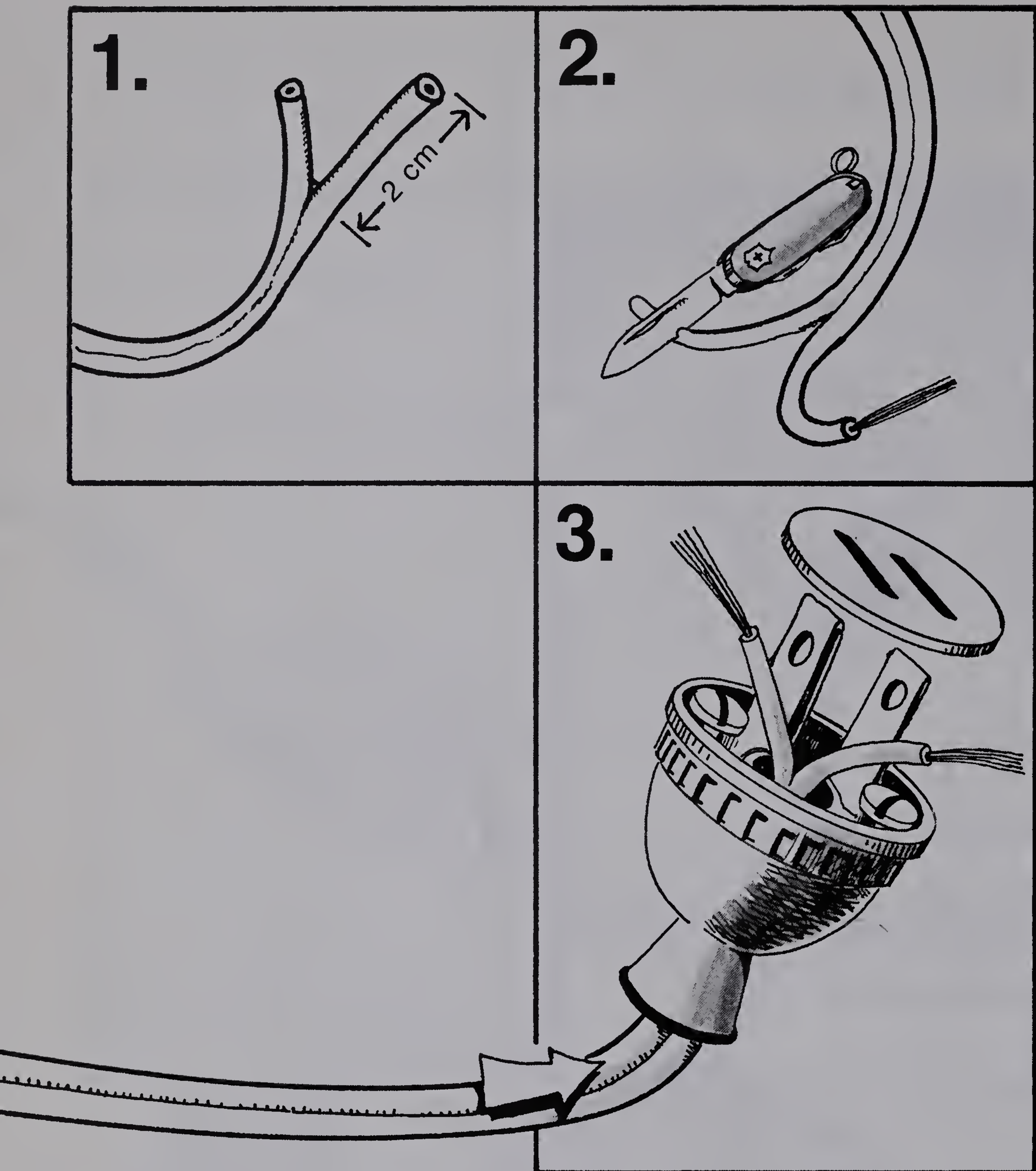


Figure 14–1

B. A snap-on plug is very easy to install. But you can use it only on a flat, rubber-coated, two-wire conductor. Do not strip off any insulation. Just insert the end of the wire into the opening as far as it will go. Snap down the lever.



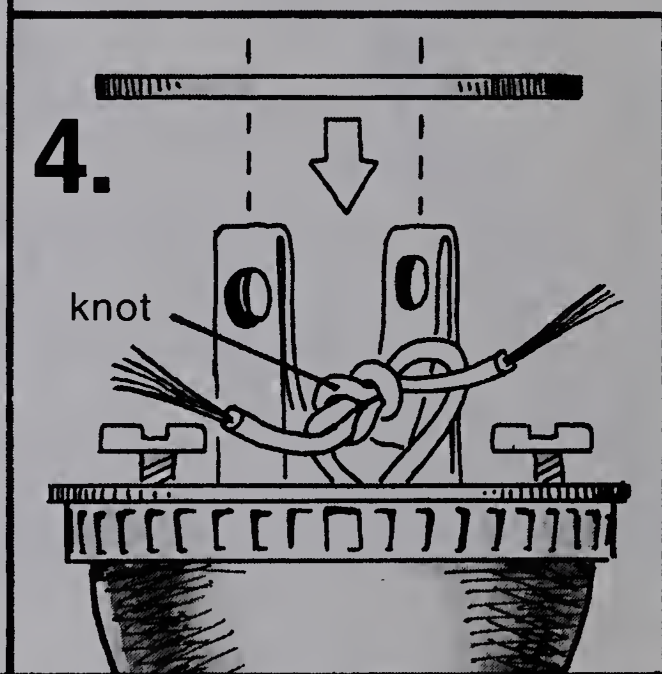


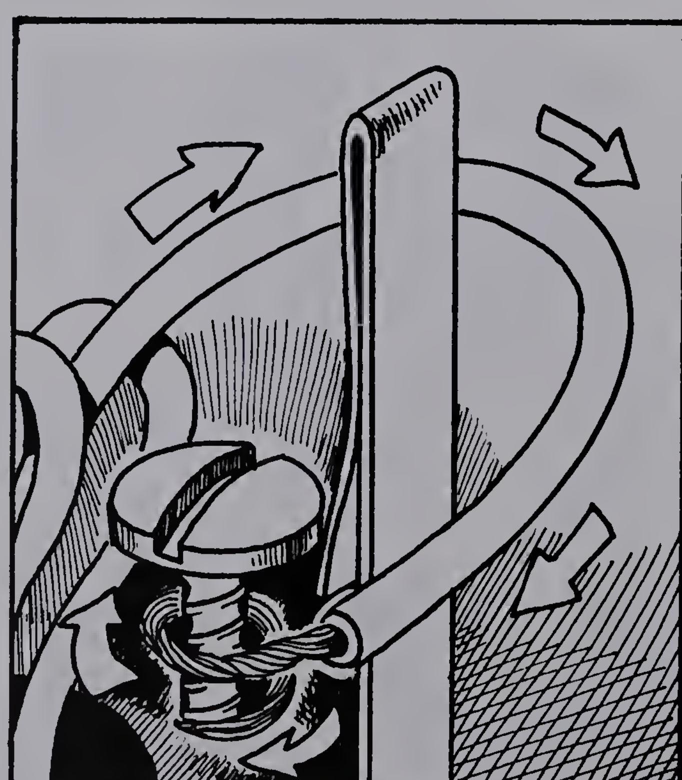
C. To install a two-prong, screw-on plug, you first have to separate the two wires and strip about 2 cm of insulation from the end of each wire.

D. Remove the protection cover from the new plug.

E. Insert both wires through the center hole in the new plug.

F. Tie a knot in the wires. Push the knot down between the terminals.





G. Twist the end of each wire. wire. Then curve each wire clockwise around a terminal. Wrap the bare wire around the screw that connects to the same terminal the wire is around. Be sure that the wire curls around the screw in the same direction that the screw turns to tighten. Tighten the screws. There must be no strands of wire that are not tucked under the screw head. If there are, do it again.

• 14–1. Look at Figure 14–2. Is A or B the right way to wrap a wire around a screw? Why?

14-1. A. As the screw is tightened, the wire wraps more tightly around it.

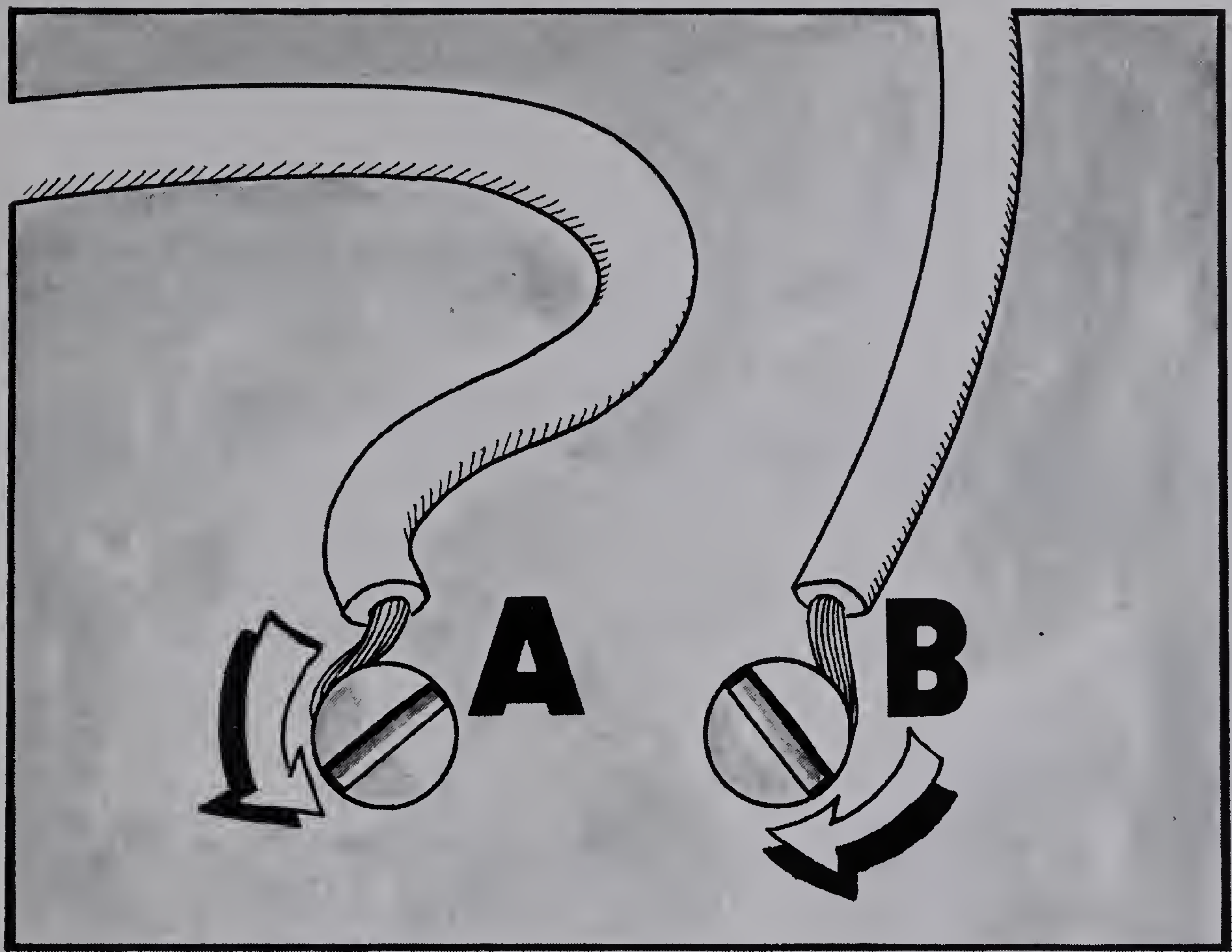


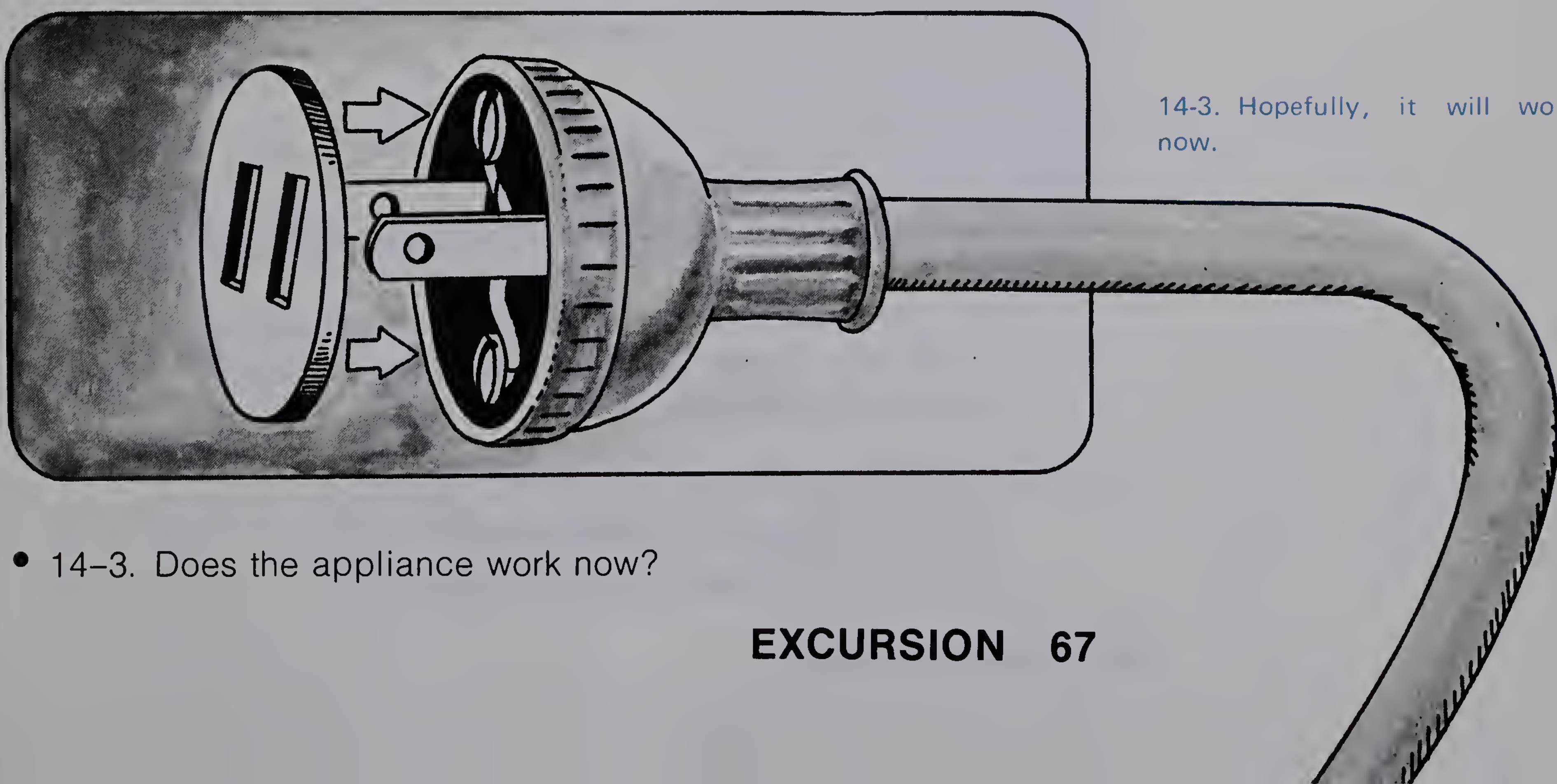
Figure 14–2

• 14–2. What might happen if a tiny strand of wire is not securely under its screw head?

14-2. It could touch the other wire or prong and cause a short circuit.

H. Replace the protective cover on the plug. Plug it into an outlet.

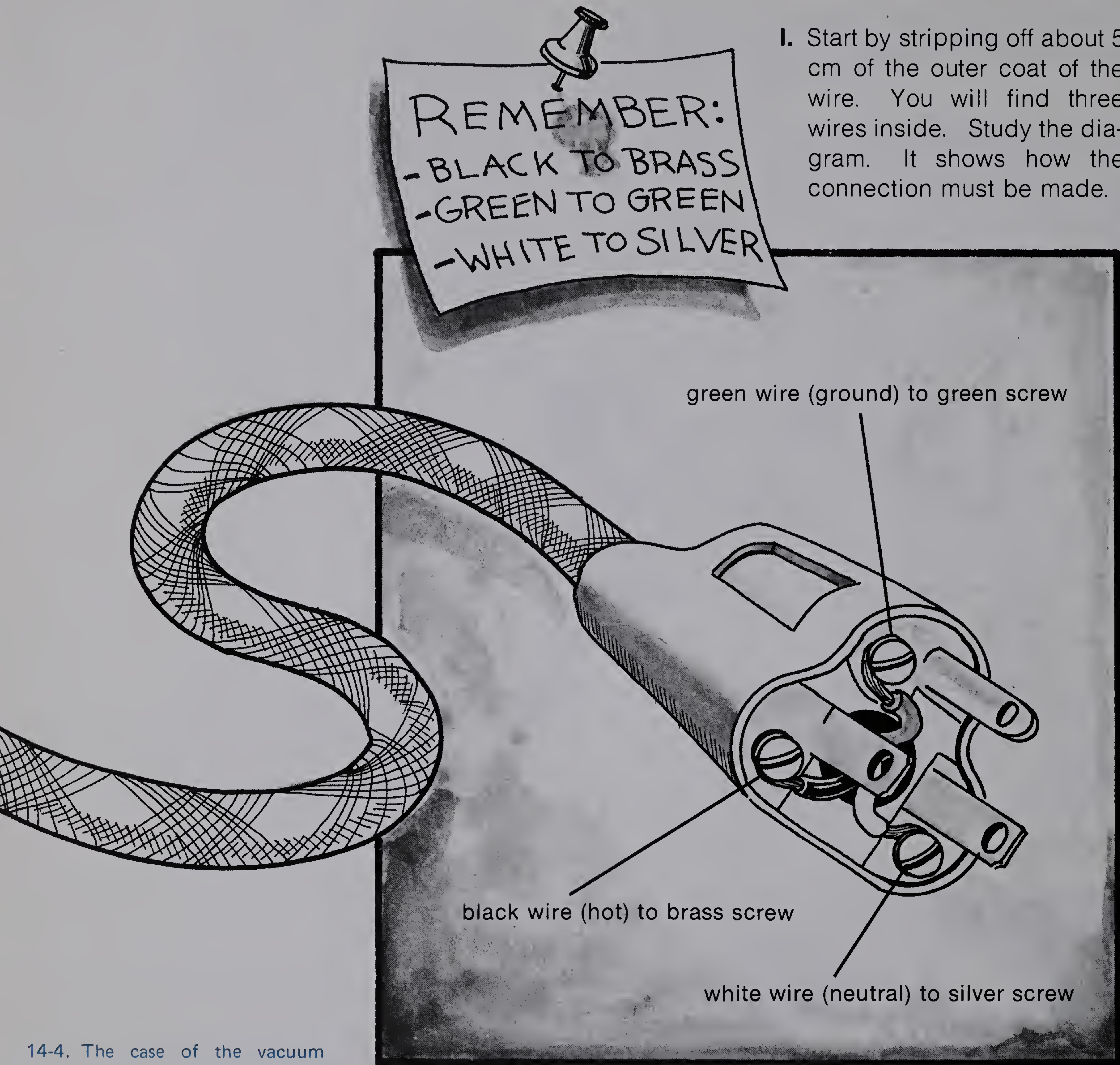
14-3. Hopefully, it will work now.



• 14–3. Does the appliance work now?

Installing a three-prong plug is more complicated. You have to be sure that each wire is connected to the correct terminal.

I. Start by stripping off about 5 cm of the outer coat of the wire. You will find three wires inside. Study the diagram. It shows how the connection must be made.



14-4. The case of the vacuum cleaner will no longer function as a ground. It will be "hot"!

14-5. COLOR CODING FOR WIRE AND SCREW

WIRE	WIRE COLOR	SCREW COLOR
Hot	Black	Brass
Neutral	White	Silver
Ground	Green	Green

• 14–4. The green wire (ground) of a vacuum cleaner connects to its case. What is the danger in connecting the green wire to the brass screw of a plug?

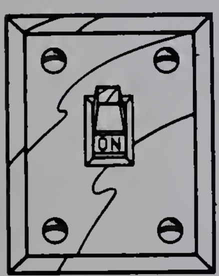
★ **14–5. Make a table like the one in Figure 14–3. Fill in the table giving the correct color code for wires and screws in wiring a three-prong plug.**

COLOR CODING FOR WIRES AND SCREWS

WIRE	WIRE COLOR	SCREW COLOR
Hot (high voltage)	(?)	(?)
Neutral	(?)	(?)
Ground	(?)	(?)

Figure 14–3

Instructions for installing the wires in a three-prong plug are similar to the two-prong plug. Start at Step C and follow the directions through Step H. Just be sure to follow the color code in Step I when you fasten the wires. Have your teacher check the connections before plugging it into wall outlets.



Activity 15
Small Heating Appliances

ACTIVITY EMPHASIS: A bimetallic strip is the "timing" device in most electrical heating devices.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.
See also Advance Preparation, p. TM 5.

Instructions for constructing the thermostat assembly are found in Advance Preparation, p. 9.

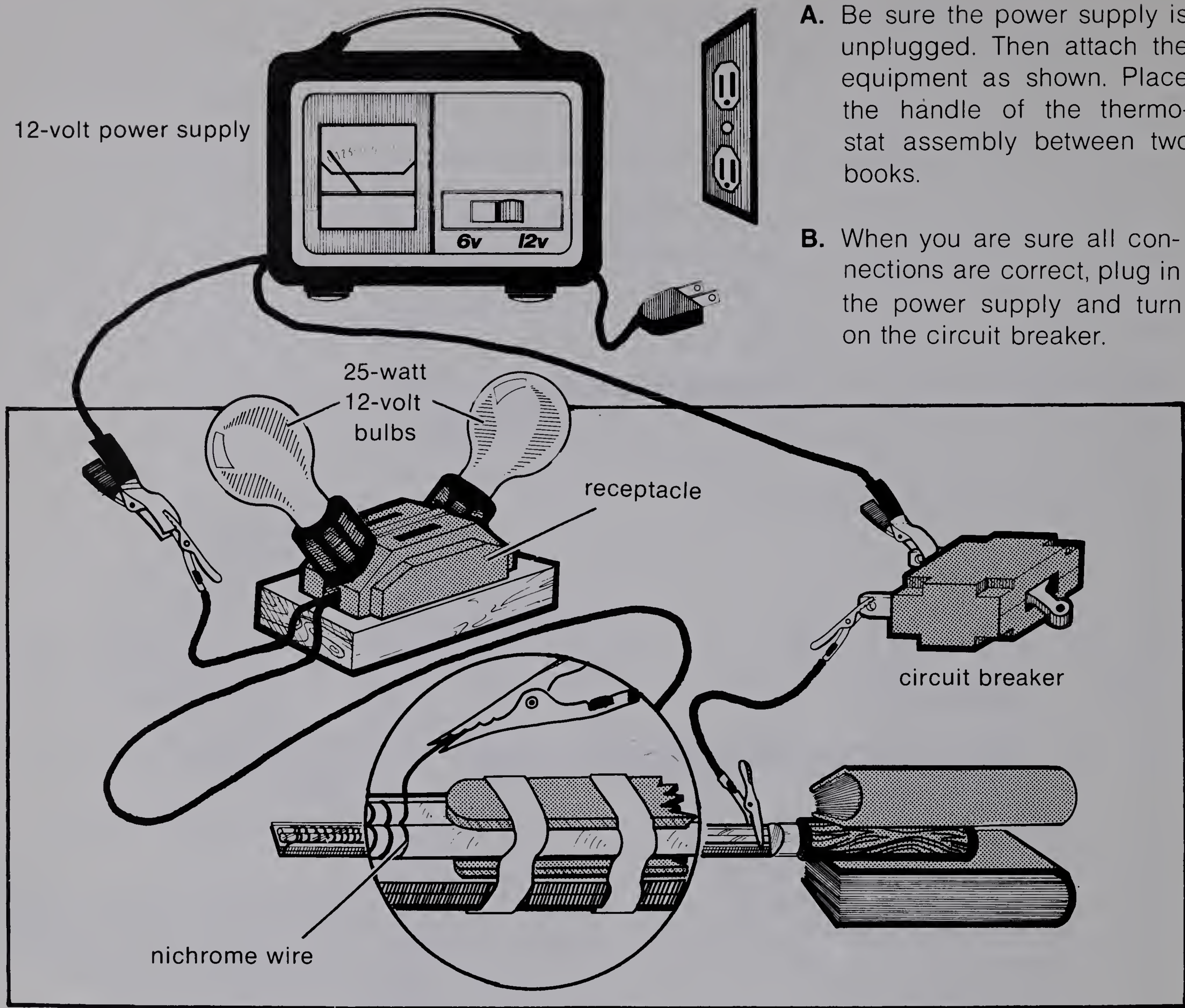
Have you wondered how a toaster "knows" when to stop toasting? Or how an iron "knows" when to stop heating up? Or how heaters and air conditioners "know" when to shut off? A special device—the thermostat—is the "brain." To see how a thermostat works, you will need the following materials:

- thermostat assembly with coil of nichrome wire
- circuit breaker, 5 A
- 2 bulbs, 25-watt, 12-volt
- 2 bulb sockets
- power supply, 12-volt DC
- 3-outlet receptacle with lead wires attached
- 2 books
- 2 electrical leads

CAUTION

If adjustments need to be made, be sure to unplug the power supply before adjusting the connection.

Be sure your hands are dry when working with electricity.



A. Be sure the power supply is unplugged. Then attach the equipment as shown. Place the handle of the thermostat assembly between two books.

B. When you are sure all connections are correct, plug in the power supply and turn on the circuit breaker.

15-1. They glow brightly at first, then go off and on.

15-2. It is changed to heat energy.

• 15–1. What happens to the light bulbs?

★ **15–2. What happens to the electrical energy that flows through nichrome wire?**

When a wire has current in it, electrical energy is changed into heat. If you used copper wire instead of nichrome wire to make a heating element, you would be in trouble. If you used thick copper wire there would be so much current that the circuit breaker would trip. If you used a thin copper wire, the wire would break or melt when it got hot. Nichrome is not as good a conductor as copper, so you can use a thick nichrome wire. It will not melt or break easily when it is red hot.

Three appliances that use coiled nichrome wire are shown in Figure 15–1. Notice that they also use mica or porcelain. These materials don't conduct electricity well at all. They are called *nonconductors*, or *insulators*.

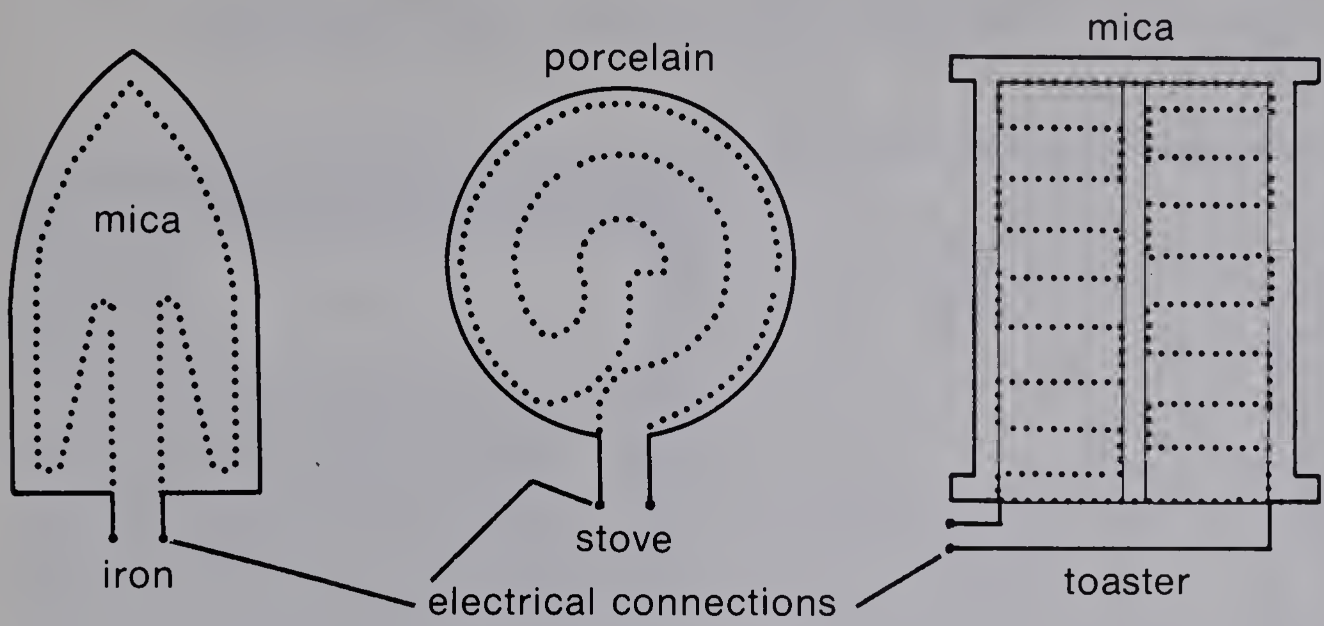


Figure 15–1

The mica and porcelain support the wires and serve as insulation by keeping the wires from touching the metal case of the appliance. That protects you from getting a shock.

• 15–3. Why are glass rods used on your thermostat assembly?

15-3. They are nonconductors of both heat and electricity.

Figure 15–2 illustrates how bimetallic strip-type thermostats work in toasters, house heaters, and other appliances.

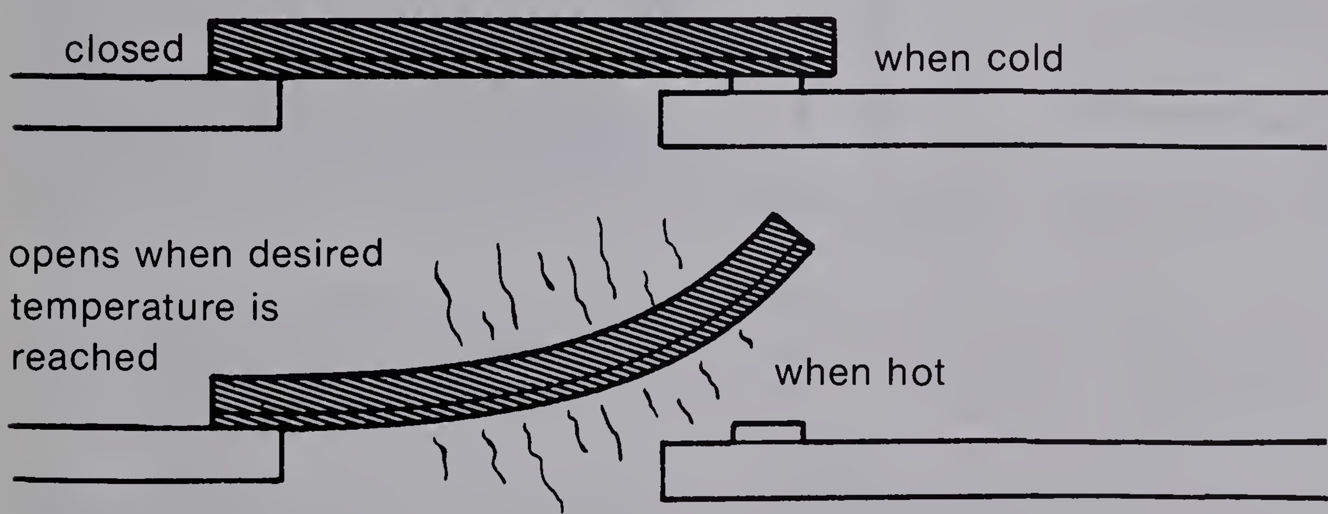


Figure 15–2

You set a thermostat at the temperature you want. When that temperature is reached, the thermostat breaks the current path and the electricity stops flowing. Then, the toast pops up or the heater shuts off or the air conditioner shuts down.

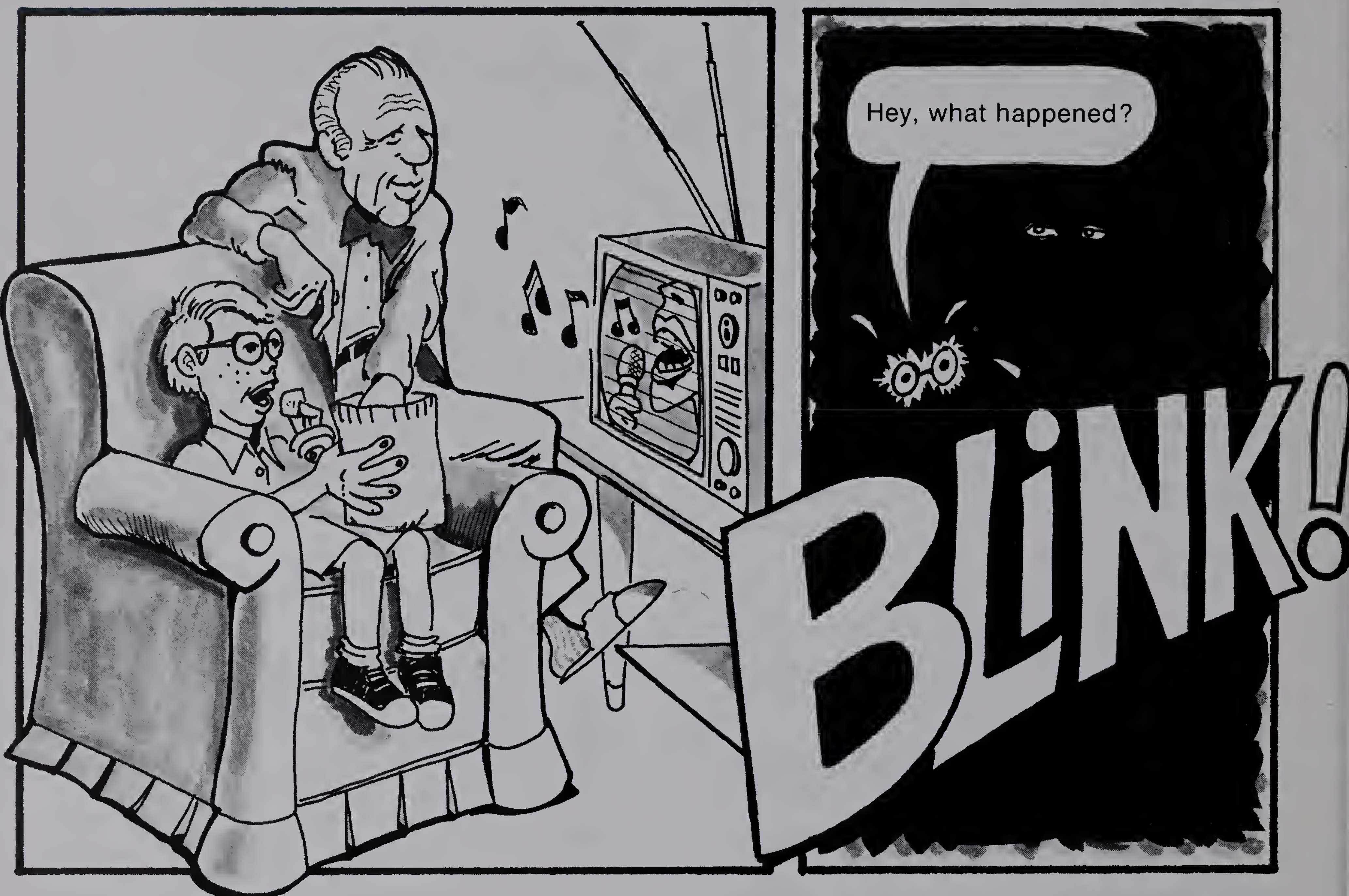
★ **15–4. How is a circuit breaker like a thermostat?**

15-4. Both use a bimetallic strip which, when heated, bends and breaks the circuit.

ACTIVITY EMPHASIS: It is helpful to identify circuits by the fuses or circuit breakers that protect them.

MATERIALS PER LAB GROUP
See Materials and Equipment, p. TM 3.

Activity 16
Your Home Circuits



Snap! A fuse blows or a circuit breaker trips. It can and probably will happen sometime in your home. How would you find a blown fuse or the tripped circuit breaker? How do you know what other appliances or outlets are affected?

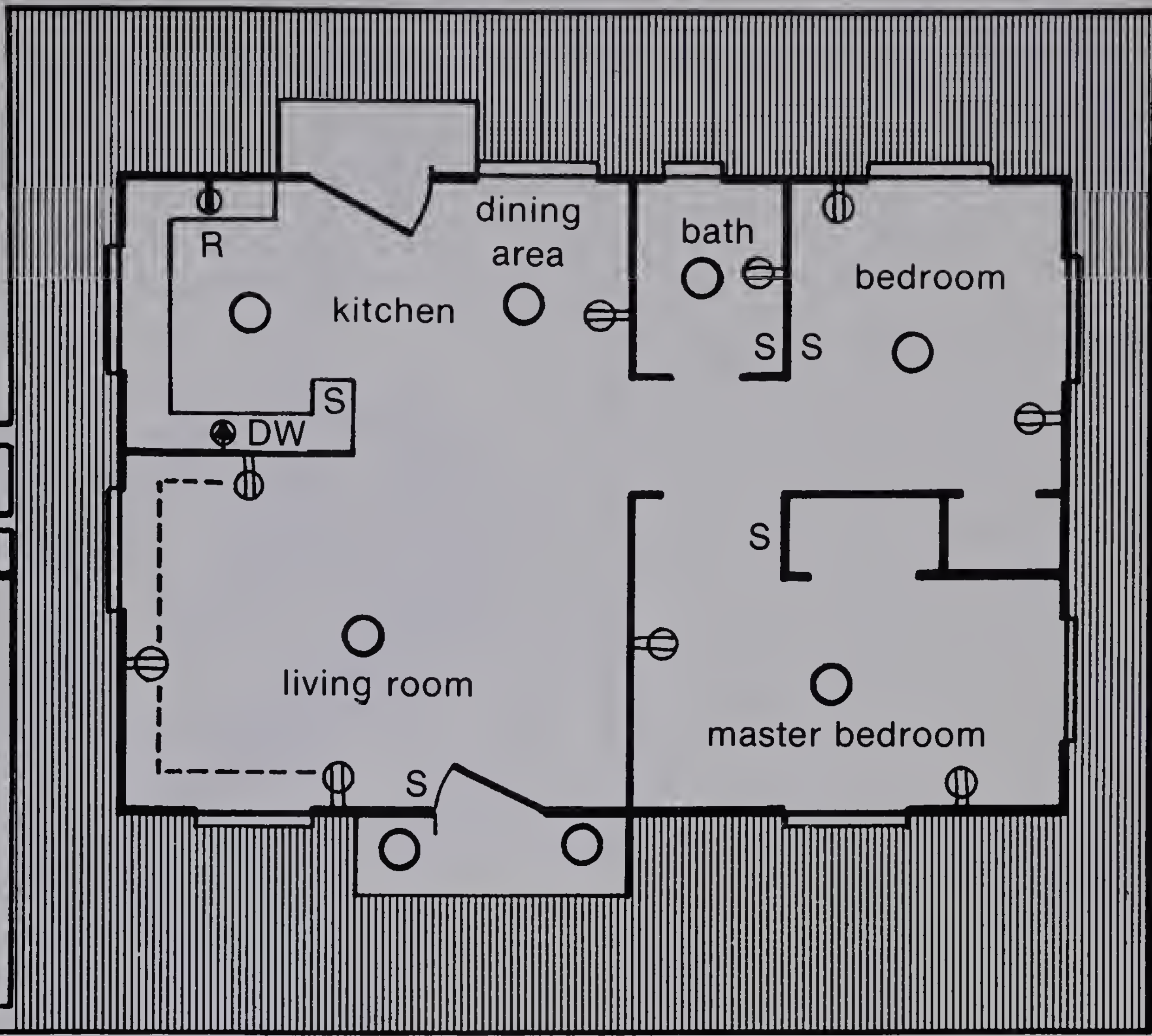
The answers are easy when you're prepared. This activity will give you that preparation. It should also help everyone else in your home. All you'll need besides paper and a pencil is a lamp or a circuit tester.

CAUTION **Be sure your hands are dry when working with electricity.**

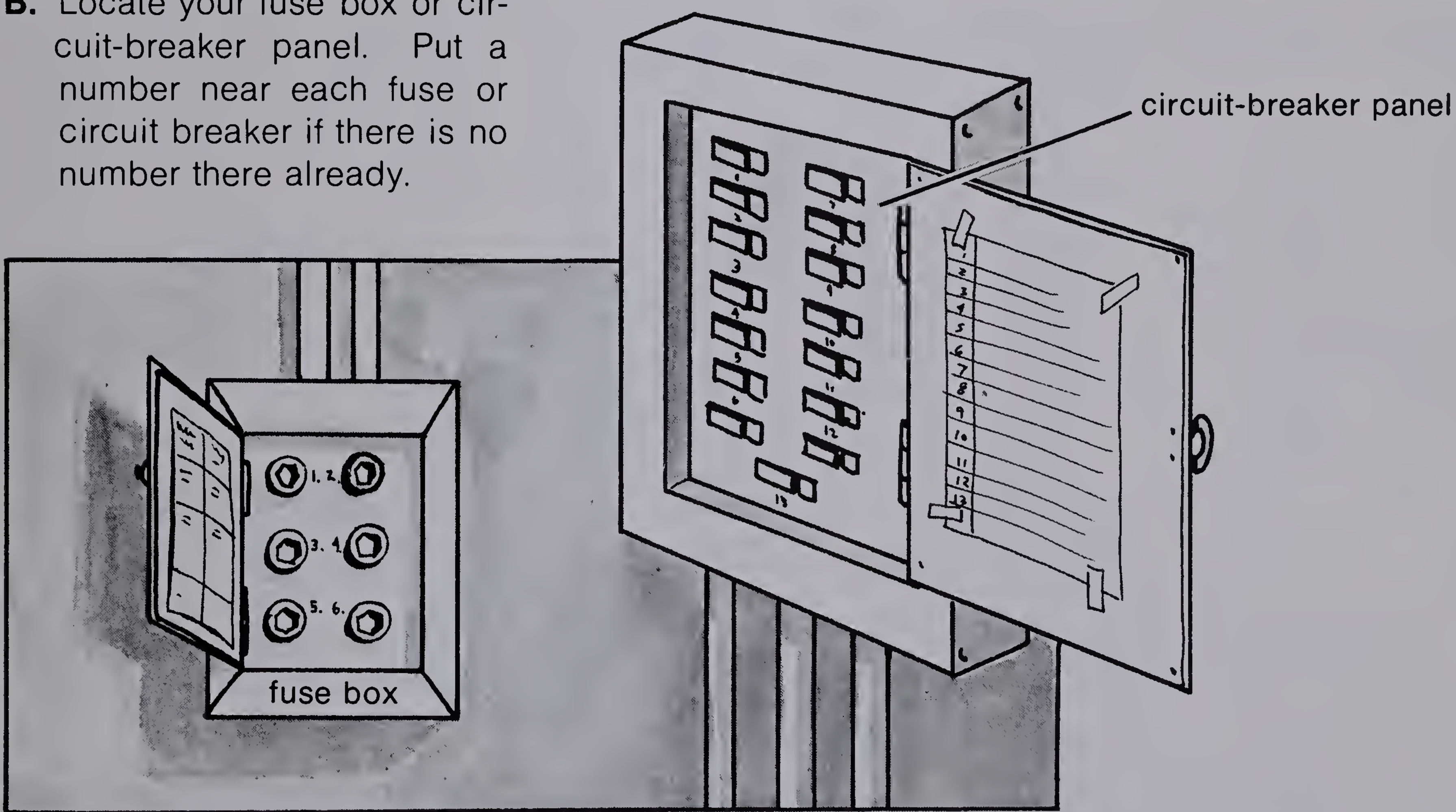
A. Draw a floor plan of your home. Show the location of all floor receptacles, light switches, and major appliances. You might like to use the commonly accepted symbols shown in the sample floor plan.

KEY

SYMBOL	ITEM
	Wall receptacle
	Lighting outlet
R	Range (stove) outlet
DW	Special-purpose outlet. Use subscript letters to indicate function (DW = dishwasher, CD = clothes dryer, etc)
S	switch



B. Locate your fuse box or circuit-breaker panel. Put a number near each fuse or circuit breaker if there is no number there already.



- 16–1. Which does your home have a circuit-breaker panel or a fuse box? Where is it located?

16-1. Answers may vary.

FUSE-CIRCUIT CHECKLIST

FUSE NO.	FUSE SIZE	CIRCUIT AFFECTED
1	20 amps	bathroom/bedroom
2	20 amps	clothes washer/dryer
3	10 amps	living room/kitchen
4	20 amps	dining room/bathroom
5	30 amps	kitchen appliances
6	60 amps	range
7	20 amps	master bedroom/living room
8	20 amps	dining room/bedroom

Figure 16–1

Here's just one more thing you should do. If you have any electric clocks in the house, reset them to the right time!

16-2. Fuses 1 and 4.

★ **16–2. Look at the sample chart in Figure 16–1. Which fuse(s) might have blown if the bathroom circuits are not working?**

16-3. With glass-face fuses, you can see which fuse has burned out and match it to the name of the appliance. With a circuit breaker, you look for the switch that has tripped.

★ **16–3. If a fuse blows or a circuit breaker trips or kicks out in your home, how can you tell quickly what circuits were affected?**

16-4. By comparing the name of the affected room or appliance to the fuse or circuit-breaker number.

★ **16–4. When a fuse blows or a circuit breaker kicks out in your home, how can you tell quickly which appliance may have been the cause?**

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ISIS Permanent Staff

Ernest Burkman, Director (1972–)
David D. Redfield, Associate Director (1974–)
William R. Snyder, Associate Director (1974–)
*Robert Vickery, Associate Director (1973–74)

Tedd Arnold (1973–)
Denis Blakeway (1974–)
Calvin E. Bolin (1973–)
Drennen A. Browne (1974–)
*Robert Buchanan (1973–75)
Marcia Bujold (1974–)
*David L. Camp (1973–74)
Gwendie Camp (1974–)
Jerome L. Ciesla (1973–)
Clifton Bob Clark (1975–)
Robert L. Cocanougher (1972–)
Sara P. Craig (1973–)
Stewart P. Darrow (1973–)
*Allan D. Dawson (1972–74)
*Joel Dawson (1972–73)
Gene Floersch (1975–)
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*Barney Parker (1973–74)
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